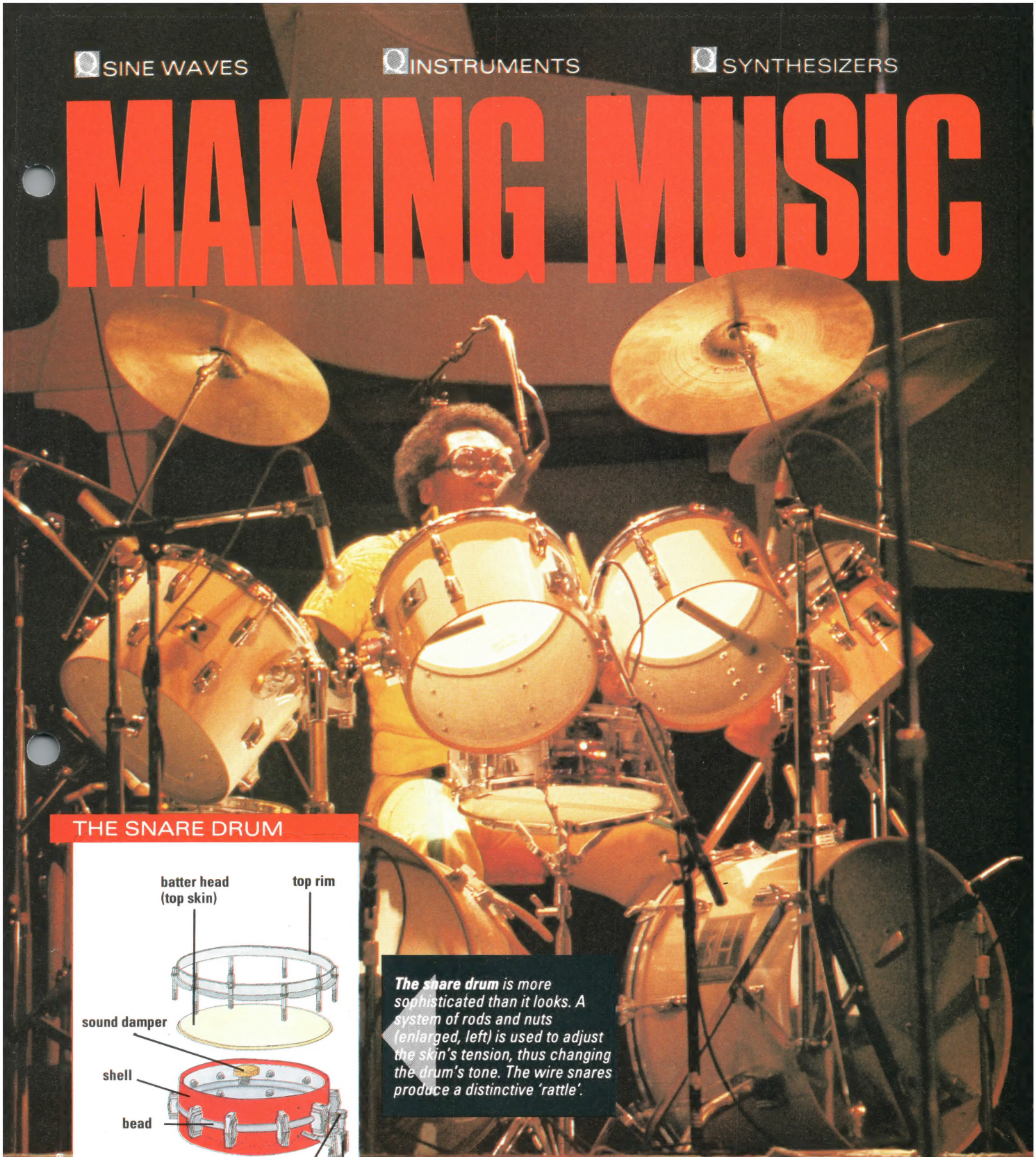
MAKING MUSIC



THE SNARE DRUM

Caroline Brodie

The share drum *is more sophisticated than it looks. A system of rods and nuts (enlarged, left) is used to adjust the skin's tension, thus changing the drum's tone. The wire snares produce a distinctive 'rattle'.*

A standard drum kit *has snare drums, bass drums, kettle drums and cymbals, all of which make different sounds.*

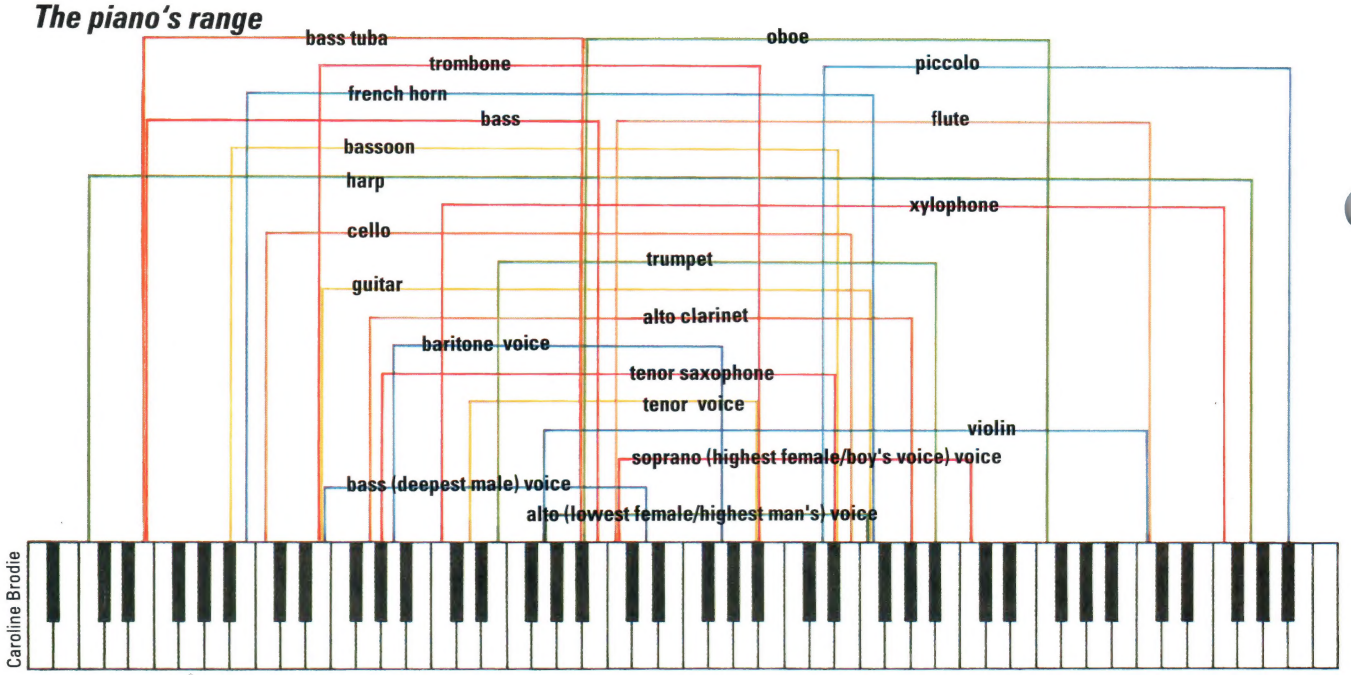
MUSIC IS HEARD ALL AROUND the world. It is played for relaxation, for dancing – and even for marching. We know music when we hear it: the sound of a door slamming isn't music, but a record on the radio or a concert – these *are* music.

Music is a series of sounds arranged in such a way that people – or some people, at least – enjoy them. Musical sounds are usually notes. The difference between notes and noises is that the sound waves forming notes are regular and repetitive, while those making a noise are not. Any series of notes that we like we can call music. Usually we can recognise and remember it; you can whistle a tune, but you can't whistle a door shutting.

You can make music in many different ways. Some instruments

Spectrum Colour Library

The piano's range



Caroline Brodie

***The 88 keys** of a standard piano cover the whole musical range, from deeper than a double bass to higher than a piccolo. The human voice falls in the middle.*

have strings which are plucked, like a guitar, and others have strings which are stroked with a bow, like a violin. You play wind instruments, such as flutes, trumpets and saxophones, by blowing into them, and you play percussion instruments, such as xylophones and drums, by hitting them.

All instruments have their own special sound, which is different from all the others. There are the zinging strings of the violin, the honk of the sax and the strum of the guitar. Even when the very same note is played on two different instruments – a flute and a trumpet, for example – it sounds different.

The secret of why different instruments have different sounds lies in the shape of the sound waves they make and in the way the sound waves change during the time you hear the note.

The simplest sound

GRAND PIANOS

Steinway & Sons

***Grand pianos** need a massive cast iron frame to withstand the pounding they get. The tone comes from the wooden case that fits closely around its frame. The keys and the hammers (right) are made separately, and they are only installed once the case is finished.*

Steinway & Sons

The best known piano makers are Bechstein, Yamaha and Steinway. Steinway recently made its 500,000th piano (above) which has the signatures of the world's most famous pianists inlaid into the wooden case. Eighty percent of a Steinway grand is hand made – the most difficult part being the curved side panels, which are made from 22 layers of wood. Six men are needed and they have only 20 minutes to finish before the glue sets.

– a pure tone – has a sound wave which is very even in shape and is known as a sine wave. This is what is produced by the Greenwich Time Signal (the pips) or a tuning fork. But the sound waves of musical instruments are not single sine waves – they are a combination of many different sine waves. The sound wave of a flute, for example, is quite different to that of a clarinet or a violin.

Harmonics

What makes these waves complex, and not simple, is their harmonics. Whenever you play a note on a musical instrument, many other notes are made at the same time. They are called harmonics and although they cannot be heard separately, it is the mixture of them and the note that was originally played – the fundamental – that makes up the sound waves. The characteristic sound of a note from a particular instrument is known as its timbre.

Timbre helps you tell apart instruments from the same family, such as two brass instruments. But there is another factor which helps make different families of instruments sound different – the way their notes change with time. A piano note comes in very quickly and gradually fades away. A clarinet, on the other hand, comes in more gradually and can be kept going by the player.

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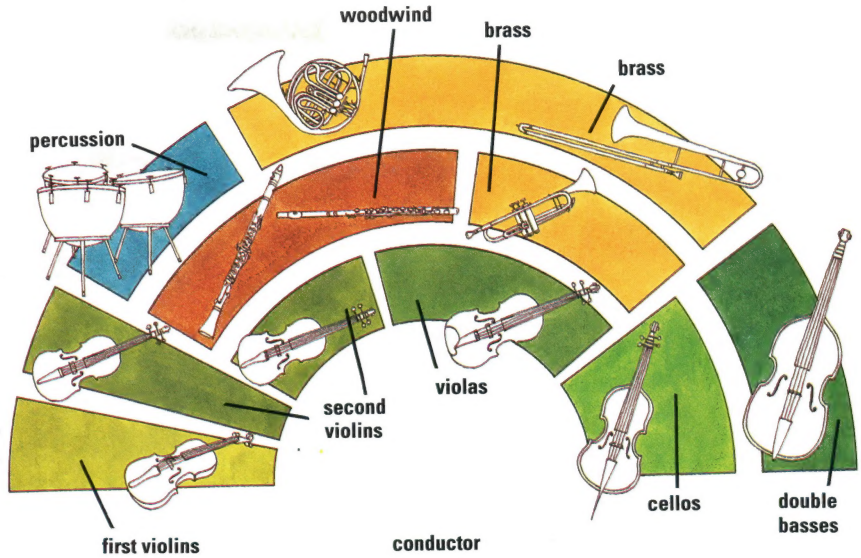


Caroline Brodie

***Orchestras** are usually arranged with the strings at the front and the louder brass and percussion at the back.*

***Brass instruments** are hand made by stretching and shaping the brass tubing with tools called mandrels.*

***Electric guitars** have taken over from violins as the most popular stringed instruments in popular music. While the violin's wooden body amplifies its sound, the electric guitar needs an amplifier to do so.*

Columns of air

There is a huge variety of instruments in use around the world. Whatever they sound like and however they are played, they all have one thing in common – something vibrates when they are played. All sounds are produced by objects vibrating – and music is no exception. So strings are set vibrating in stringed instruments, and columns of air in wind instruments.

Most instruments also have one or more resonators, which enable them to be heard well and give them their character. Solid objects have frequencies at which they naturally vibrate. Tap a glass – the sound you hear is the result of the glass vibrating at its natural frequency.

You can make something vibrate at its natural frequency by

Tony Stone Photo Library, London

Casio Electronics Co Ltd

Nic Broomhead/Rufford Craft Centre

***Violins** are precision-made. Slight changes in the position of the bridge under the strings or the soundpost inside the body can make an enormous difference to the sound.*

playing that frequency near it; this is called resonance. Musical instruments use the resonance of the materials of which they are made to produce their sound. A violin string vibrating on its own would hardly make a sound, but when it is connected to all the panels that make up the body of the violin, it sets them resonating and you hear the sound of strings.

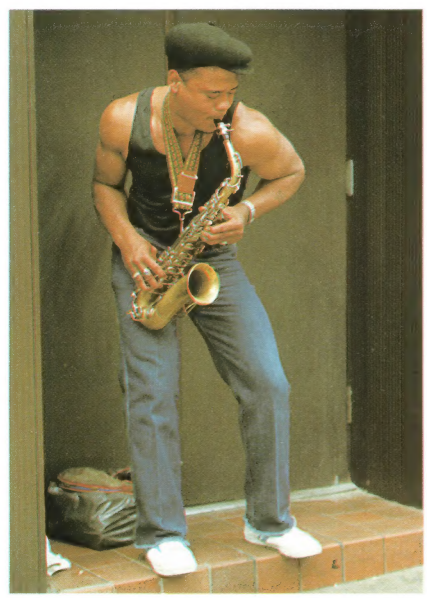
There are many other stringed instruments besides guitars and violins. The mysterious sound of India is captured by the instruments of that country, including the tamboura, which is plucked to give a droning, hypnotic melody, and the twangier sitar, which is also plucked.

The range of percussion instruments around the world is phenomenal. The familiar cymbals can be clashed together or hit with a stick. In the tropics, gourds are dried and made into rattles.

Not everybody agrees that standard instruments are all that can

Spectrum Colour Library

***A reed** vibrated by the player's breath helps create the sound of many woodwind instruments. The clarinet (right) has a single reed; the bassoon a double reed.*

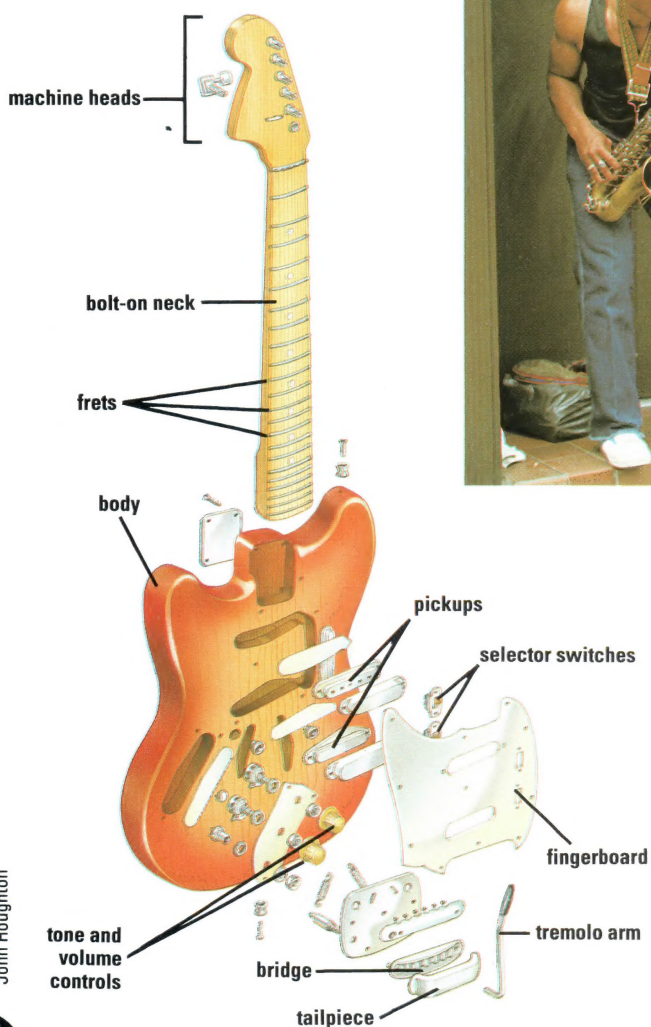


ZEFA

make music. Many pop groups and modern composers use synthesizers (see Synthetic Sound, Futures, pages 71–74) that produce the sound waves of other instruments electronically, or make sounds of their own.

The American composer John Cage has composed a piece called 4'33". For four minutes and 33 seconds, any number of players with any kinds of instruments stand silently on a stage.

The 'music' is just any sounds – such as coughs or sighs – that musicians or audience happen to make, plus any outside sounds.



John Houghton

***Saxophones** have a clarinet-style reed and mouthpiece, but a brass body for a brighter sound.*

***The electric guitar** has a solid body and bolt-on neck. The body is fitted with magnetic pickups. These detect the strings' vibrations and convert them to electrical signals. An amplifier amplifies the signals and speakers turn the current back into sound.*

Just amazing!

HIGHLY STRUNG

WOODEN-FRAMED PIANOS HAVE BEEN KNOWN TO SNAP IN HALF WHILE BEING TUNED BECAUSE WHEN FULLY TIGHTENED, THE PULL OF ALL 88 STRINGS AMOUNTS TO SOMETHING LIKE 20 TONNES.

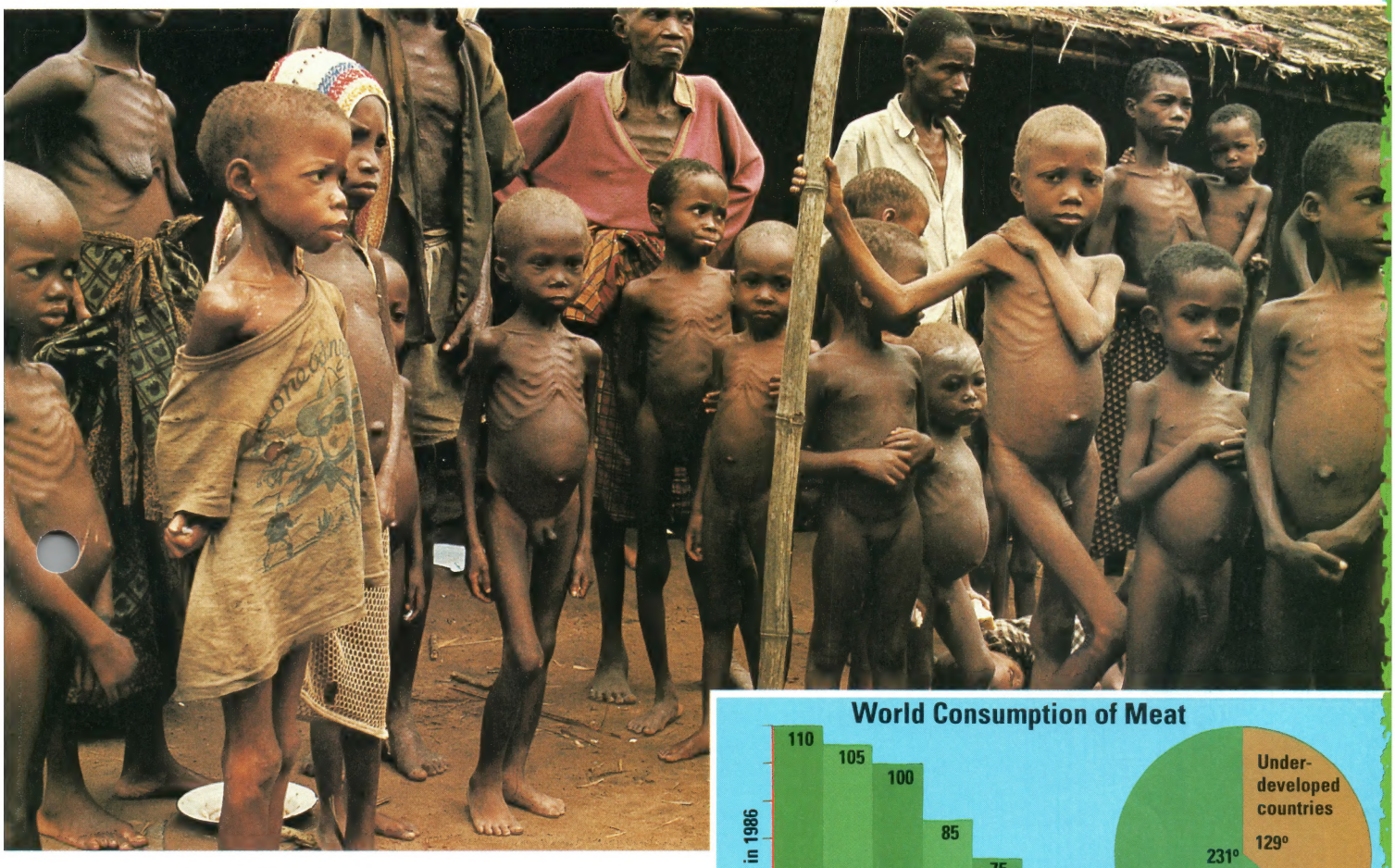
Paul Raymonde

FOOD AID

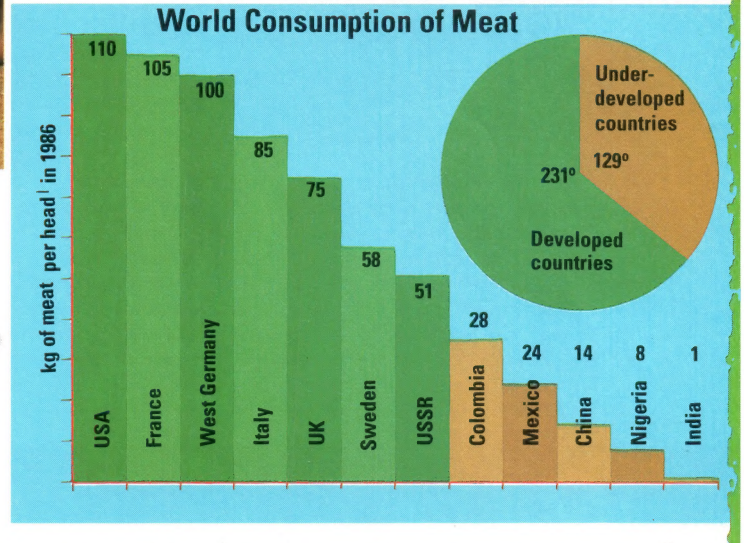
- THE RIGHT TOOLS
- CASH CROPS
- THE GREEN REVOLUTION

Farmers Weekly

***Grain waiting** on the docks. Shipping costs prevent European grain mountains being sent to famine areas.*



Stuart Heydinger/Telegraph Colour Library



***Developing nations** eat a much larger slice of the 'meat pie' than the Third World, which has three times as many people. The largest consumers are the Americans with 800 kg a year each. Some Africans only eat 22 kg.*

PLANET EARTH GROWS enough food to feed all the people living on it. Agriculturalists have estimated that, if today's foods were distributed evenly, everyone in the world would have enough to eat. In fact there could be enough left to feed several hundred million extra people. Yet millions starve.

Two thirds of the world's population lives in a state of permanent hunger. It takes little to tip the balance into mass death, by starvation, and disease, by malnutrition. Tragically, many of the poorer countries are likely to suffer war, drought or flood – occurences that can so easily lead to famine and mass starvation.

At first sight, the solution appears simple. Intensive farming in Europe and North America is producing far too much food for the people who live there. Yet in Africa, parts of Asia and South America, people are dying every day from lack of food. Why can't the developed nations' food surpluses feed them?

In 1988, the European Community spent about £16 billion, almost two-thirds of its money, on agriculture. Most went on buying up and storing surplus crops and animal produce. Otherwise European farmers could not sell their products profitably and thousands would go out of business.

Another reason why surpluses are often necessary is the perilously thin line between a large reserve and a potential shortage. Britain's 1.7 million tonnes of surplus grain would only last a few months, if the next harvest failed.

Caroline Brodie

A GENTLE GIANT

Camels tread daintily, in spite of their size and cumbersome appearance. Their feet, with two toes joined by a web of skin, were designed by nature for walking on soft sand. Equally, they can walk over newly-planted crops without damaging tender young plants. Cattle, on the other hand would wreak havoc and also damage the ground with their sharp cloven hooves. The camel population in African countries is, therefore, being encouraged to grow.

One reason is that the food industries, including the giant bakeries, are geared to a year-round supply. There can be no 'slack season', with huge ovens costing millions of pounds lying idle.

Sending extra food to countries where it is needed also invites many problems. A grain-carrying cargo ship costs thousands of pounds a day to operate. Once the ship reaches its destination, the food must be unloaded and distributed. Again, someone has to pay. Countries that produce excess food might feel that selling off stocks cut-price could be possible, but financing its transport half way around the world is too expensive. To compound the problem, the countries where famine is rife have little spare cash to pay for importing extra food supplies.

A share-out of world food appears economically impossible; however attempts have been made to encourage Third World countries to grow more of their own food.

The 'Green Revolution' of about 40 years ago was an attempt by farmers in Europe and North America to breed higher-yielding and more disease-resistant strains of cereals such as wheat, maize and rice. These strains were then grown in parts of Asia and South America.

The results were spectacular: India, for example, grew about 50 million tonnes of cereals and similar basic food crops in the early 1960s. By 1970, this had doubled, while the country's food imports had fallen by half.

Bitter harvest

But success was short-lived. As the price of oil leapt in the 1970s so the cost of vital fertilizers soared out of reach of most of the poorer farmers. Production levelled off – in some places it fell.

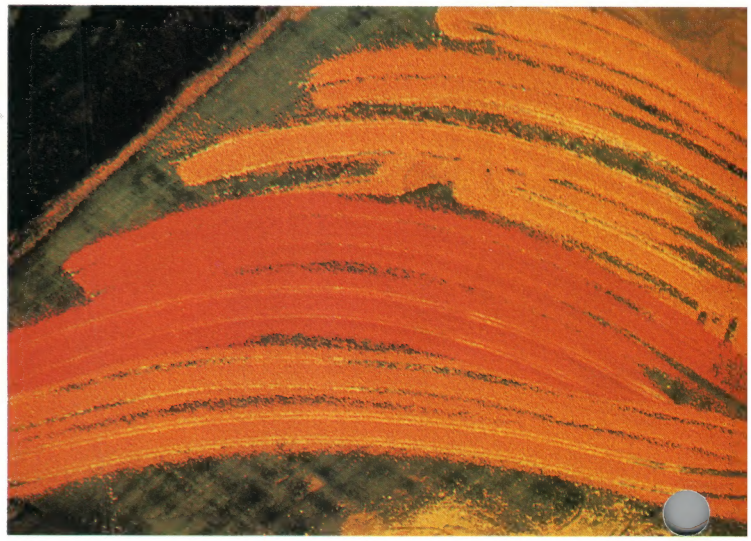
Vast areas of the Sahel region in central west Africa, for example, were at one time used for growing peanuts, cotton and other cash crops (a cash crop is one grown purely for money to buy food and fuel for the farmer and his family). Soil erosion, plant diseases and highly intensive farming gradually ruined the soil. At the same time, world markets in cash crops became depressed. Hunger spread and the richer countries that had once bought the peanuts and cotton were asked for aid instead.

Hard lesson

Underdeveloped countries' poorer farmers, therefore, have since learned to understand their own needs. The key phrase is 'appropriate technology'. For example, it is no use selling a combine harvester to a poor farmer who has neither the money, nor knowledge to operate it.

The farmers have little money to buy and run machines and their farms are far too small to make efficient use of them. The hand-operated rice transplanter, on the other hand, was especially developed for the small farmer and was one of the successes of the Green Revolution.

Now the search is on for plant crops that small farmers can grow using simple machinery.



Surplus oranges *are used as cattle feed in California. Elsewhere in the developed world, food surpluses are stored, left to rot, or are deliberately destroyed.*

Threshing rice *into a basket in northern Thailand. In developing countries, traditional harvesting techniques may be more appropriate than modern methods.*

Nigel Cattlin/Holt Studios Ltd

Peter Menzel

F Botts/FAO

A camel's head *hangs in a Tunisian butcher's shop. After finishing its useful life as a beast of burden, the camel is often killed for meat.*

Just amazing!

FOOD FOR THOUGHT

EVERY YEAR, THE WORLD'S RATS AND MICE EAT OVER 40 MILLION TONNES OF FOODSTUFFS – MORE THAN ENOUGH TO FEED EVERY STARVING HUMAN.

Paul Raymonde

- IRRIGATION
- HARVESTING RAIN
- SELECTIVE PLANTING

GREENING THE DESERT

DESERTS ARE GROWING – year by year vast areas of the world, particularly in Africa, are made less productive through greed, ignorance or poor farming techniques.

Taking water to dry areas is one of the most basic ways of increasing food productivity so that crops grow better, or plants that would otherwise not grow can be raised. But different situations demand different solutions. Centre pivot irrigators are one high-tech answer for large-scale farming. An immense snake-like arm, up to nearly 1 km long, circles round a central tower, spraying water from hundreds of nozzles. The arm is divided into sections, which run on wheeled bogies. Each bogie is driven by an electric motor, with the speed adjusted automatically to keep the arm straight. Pesticides or fertilizer can be added to the water as and when they are needed.

The biggest system is in South Africa, with 33 sections and covering more than 1,000 acres in a single gigantic revolution.

Low-pressure systems

Such hugely expensive machines are beyond the reach of farmers in poor countries. More appropriate are various kinds of low-pressure irrigation systems. In drip-feed or trickle irrigation, narrow plastic tubes snake across the fields. They carry water slowly but frequently, keeping the soil moisture topped up.

By contrast, a tiny state like Israel (which is roughly the size of Wales) has coped with a barren, stony terrain and low rainfall and literally 'made the desert bloom'. The answer is in technology and research.

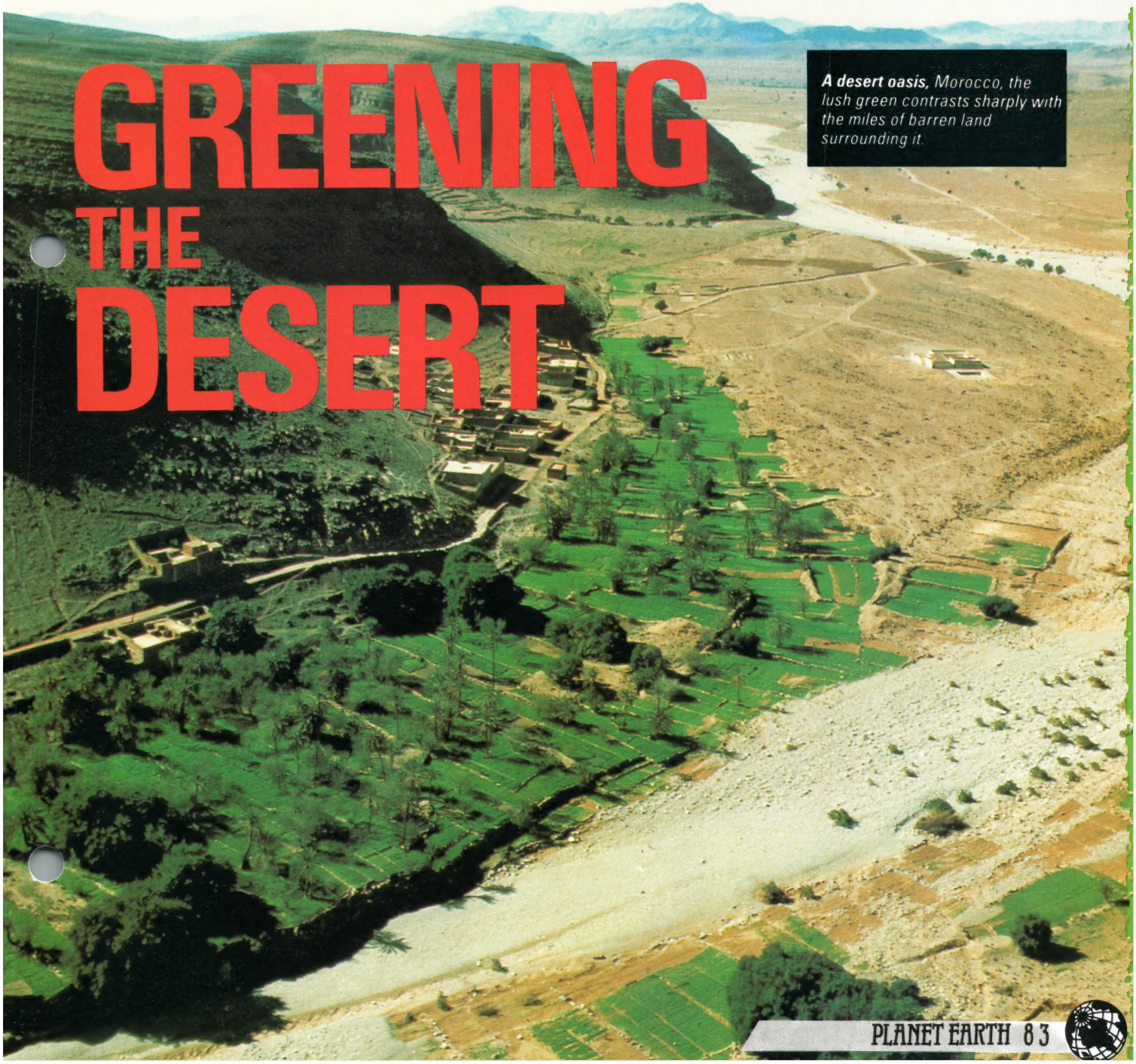
Ancient secret

Archaeologists have found that in pre-Christian times the stony Negev desert was farmed and several cities flourished there. The ancient secret was a system of hydraulic engineering now known as run-off agriculture. It consists of harvesting rainwater from high ground and concentrating it on small terraced fields below.

Harvesting dew

Israeli scientists are also researching techniques for obtaining water from the air by dew-trapping devices, and from the sea by desalination (removing the salt).

In Kenya, the Baringo Fuel and



Holt Studios

A desert oasis, *Morocco, the lush green contrasts sharply with the miles of barren land surrounding it.*

Ted Spiegel/Colorific!

Centre pivot irrigation, *USA. The Navajo project collects water from the Colorado river basin and uses it to grow crops in the surrounding desert.*

Fodder Project has shown on a small scale how the future can be tackled successfully.

About 100 years ago, the Baringo area was cloaked in dense, lush grass as tall as a man. Then European farmers moved in and their dense herds of cattle grazed the goodness out of the soil. The local scrubby bushes were turned into charcoal, for fuel in big cities like Nairobi. The soil was bare, and stony, useless for agriculture.

Rehabilitation

Rain does fall in the region, about 600 millimetres each year. But it is concentrated in short showers too heavy for the ground to absorb. The water mostly runs away in deep gulleys, washing off the nutrients in the topsoil as it goes. So the workers dug a criss-cross system of embankments, following the contours of the field. Next time it rained, each rectangle held the water like a miniature shallow pond. Into these rectangles, grasses and a few young trees were planted.

PLANTS WITH A FUTURE

Among the many plants offering new solutions to the problems of growing crops in harsh lands are:

- The Somalian Yeheb bush: a native of arid lands, it has nutritious peanut-sized seeds
- The hairy wild potato: a wild plant whose pest-deterrent scent could be bred into other crops
- Spirulina: a tiny protein-rich alga that flourishes in the salt lakes of arid lands
- Pomelo: similar to a grapefruit but can weigh up to 10 kg; it is very rich in Vitamin C
- The winged bean: every part of this plant is edible. It promises to become the 'soyabean of the tropics'.

The Baringo people decided to concentrate on producing wood for cooking fires, plant crops for themselves, and fodder for their animals, rather than cash crops.

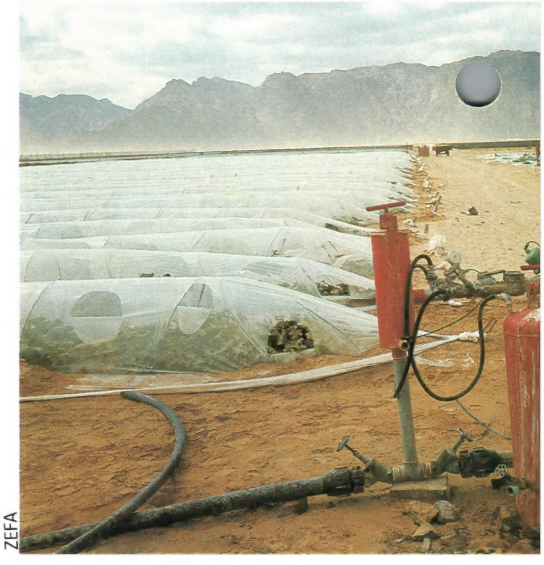
Productive plants

Various kinds of trees and grasses which could grow well in their dry climate were carefully examined. Prosopis trees from South America have been successful. Their wood is hard, for fences and building, and burns well. Their leaves and pods are fed to farm animals. A local African species of acacia also grows well in the region. It enriches the soil and its pods of beans are eaten by livestock. Another local species, the shrub *Berchomia*, produces hard wood and good charcoal, and sweet fruits for animals and people. The desert date produces leaves eaten as a vegetable, and seeds ground into flour or crushed for oil.

Grasses were planted among the trees, and cut regularly as fodder for cattle, sheep and goats. But unfortunately, farm animals, as well as wild ones from the surrounding bush, were attracted to the fields of saplings and young grass. Wood was too valuable to build fences around all the fields. The answer came in the shape of solar-powered electric fences. These deterred the animals by giving them a mild electric shock whenever they made contact with the wire. Once bought, the fences ran on the abundant sunshine and kept the marauding animals out.

ZEFA

American potatoes *can be grown in the desert thanks to this huge mechanical sprinkler. The irrigation system can be operated from kilometers away by remote control.*



ZEFA

Israel's Negev desert *has plentiful sunlight and can now support crops with a simple watering system.*

Future hope

The Baringo project has been successful – so far. It truly came from the grass roots and hopefully could be an example to others.

Paul Raymonde

***Pollutants** from a steel works often include large amounts of nitrogen and sulphur gases, as well as particles that can cause lung cancer (orange spots on X-ray, inset below left).*

Fred Maroon/SPL

CNRI/SPL

HEALTH WATCH

HEALTH HAZARDS

POLLUTION

LIFE EXPECTANCY

THE HUMAN BODY IS WELL equipped to survive in our world of pests and diseases, accidents and extremes – from temperature to stress. How well we cope with these factors depends on how much care we take over hygiene and nutrition – the two keystones of good health.

Personal hygiene means keeping the body clean, which mainly involves caring for the skin. Our skin is a very complex structure. The biggest and one of the most important organs of the body, it accounts for 7–20 per cent of the body's weight. The average 75 kg man has 5–15 kg of skin.

Most of the skin's functions we take for granted and do not notice, but healthy skin is essential to well being. We can live with one kidney or even one lung, but if one-third of our skin is damaged (for example by burns) our life is seriously at risk.

To keep our skin healthy it must be treated with care. The skin is protected by natural oils. If the skin is de-greased too well – by using too strong a soap, for instance – it will dry out and become flaky; also, certain bacteria may take advantage and cause problems or illnesses. The skin must be kept clean, but using too much soap will disturb its chemical balance. Careful washing is usually all that is needed to keep it healthy.

Nutrition

The teeth must be brushed regularly to prevent the build up of plaque – a hard coating of saliva, food particles and bacteria. If plaque builds up on the teeth, acid produced as the waste product of bacteria can cause gum disease and tooth decay.

Many diseases are caused by bad eating habits. It has been proved

***Blotches** and rashes can be caused by bacterial infection, but soap and make-up or even what you eat can have similar effects.*

SICK BUILDING SYNDROME

Chemicals given off by materials in modern buildings can cause illness in some people. Symptoms vary from headaches and drowsiness to lethargy and runny eyes.

These buildings are not factories and laboratories, where you might expect to find pollutants – they are offices. The materials used in offices appear harmless, but a bottle of typewriter correcting fluid, for example, contains chemicals that evaporate when the fluid is used. Pens, typewriter ribbons and adhesives all release chemicals, many of which are toxic.

The problem is even more acute when the materials that make up the structure of the building is considered. Wall coverings, insulation, even carpets are all sources of pollution. Harmful substances given off include formaldehyde from chipboard, benzene from inks and cleaning solutions, toluene from rubbers and ozone from photocopying machines. In addition, there are often fungi, bacteria, cigarette smoke and dust in the atmosphere.

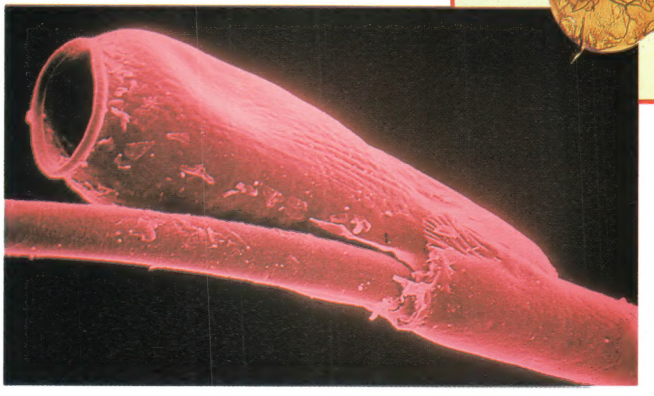
In well-ventilated buildings, these substances do not build up to noticeable levels, but modern, air-conditioned buildings have sealed windows, and their ventilation systems do not always purify the air they circulate. The result is a stale, toxic atmosphere which can make some people feel ill. This problem is one of the reasons large numbers of people go absent from work each year.

the flow of blood. A partly blocked section of the vessel can be cut out and the vessel rejoined.

The important word in any diet is balance. You need fats (and cholesterol) for normal health, but too much causes disease. This is true for everything you eat – too much causes one problem in the same way that too little causes another. A good balanced diet containing vegetables, fruits, cereals and meat contains all the protein, fat, carbohydrate, vitamins, minerals, and roughage needed for health.

What you do to your food in the kitchen can make all the difference between a healthy meal and a poor one. A potato, for example, is healthy when baked in its skin – less so if made into chips and fried.

Some diseases may be controlled that a diet high in fats and sugars increases the chances of people developing arteriosclerosis – a narrowing of the arteries (vessels that carry blood from the heart). Cholesterol (a substance found in all animal fats), is deposited on the walls of the blood vessels where it builds up, causing them to narrow. The effect is to reduce or even stop



Cath Wadforth/SPL

SPL

***The head louse** lives in human hair – it especially likes clean hair – and feeds on human blood. It 'glues' its eggs, or nits, (left) to the hair.*

environmentally. Cancer, for example, is an overgrowth of once normal cells that have forgotten how to 'turn off' their cell-multiplying switch.

Smoking is the second surest way (after inhaling asbestos) of developing lung cancer. People who regularly smoke 30 cigarettes a day increase their chances of getting cancer by more than 30 times.

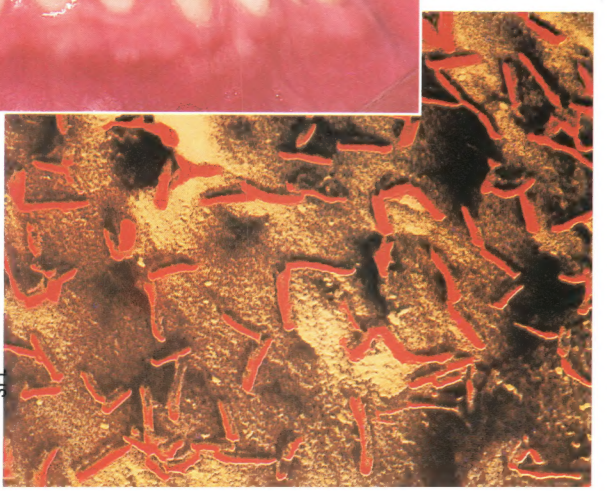
The smoke from cigarettes contains tar and nicotine. The tar blocks up the small airways in the lungs and irritates the delicate membranes lining them.

Nicotine addiction

Nicotine (a drug found in tobacco) acts on the central nervous system, making the smoker dependent on the drug. The tar and accompanying irritation of cigarette smoke cause a change in a cell's structure, which helps to turn it into a cancer cell. This altered cell divides at an abnormal rate to produce a tumour mass – lung cancer.

Some cancers seem to be more common in certain areas of the

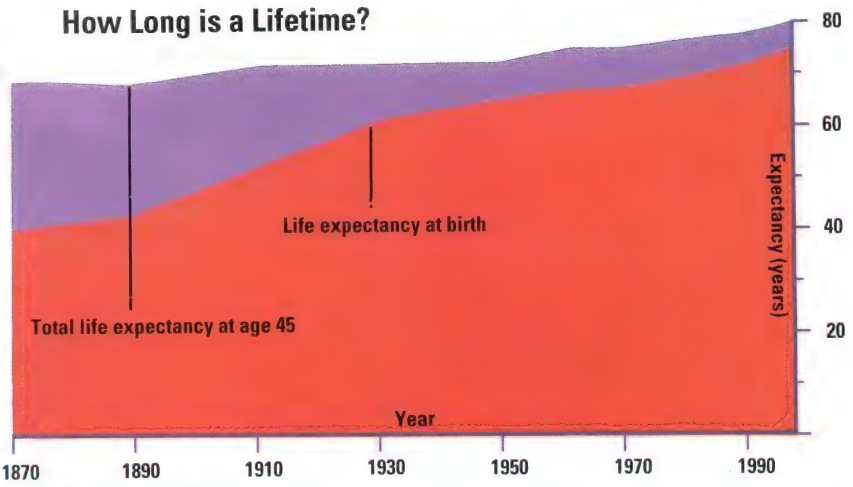
SPL



SPL

***Bacteria** (red), magnified 1800 times, feeding on plaque on the surface of a human tooth (yellow). Plaque contains food particles trapped in saliva. Frequent brushing prevents its build-up, but on neglected teeth it hardens and must be scraped off. A dye or discloser shows plaque as dark areas on teeth (above left).*

Life expectancy *in the developed world has risen – not because of advances in medicine, but because our diet is healthier and the environment is cleaner.*



Eric Grave/S.
CNRI/SPL

The tapeworm *parasite lives in the intestine, causing increased appetite, weight loss and weakness. In humans, it can grown to 10 metres long (inset above).*

Arc welding *exposes a worker to many hazards, including electric shock, burns and lung cancer (from inhaling harmful fumes).*

phere with the exhaust gases. But it is poisonous, especially to children, harming the brain.

Caroline Brodie

Freezing cold

In countries that have cold, damp winters, old people may die from hypothermia (the body gets too cold to work correctly) or from respiratory diseases, such as bronchitis and pneumonia.

We all have adaptations to live in our own environment. That is why people who live in cool climates but holiday in warm countries may burn in the sun. During heat waves, many people suffer dehydration, because their bodies are not used to extreme changes in the weather.

world. For example, in Japan, stomach cancers account for more than half the deaths from cancer. The reason for this is not clear, but it appears to be linked to diet. Yet in Japanese people living in, say, the USA, the cancer rate is between that in Japan and that in the USA. So the environment seems to be a factor that affects the chances of getting cancer – but just how is not yet understood.

The environment has a large influence on the health of a population. In tropical countries, insects and bacteria thrive in the hot weather. Many of them either cause disease or spread it. Together with poor hygiene and a lack of clean drinking water, they are a major health hazard.

In the developed world, where the spread of disease is much less of a problem, there is a greater threat from pollution. For instance, lead is added to petrol for smooth engine running and high performance and passes into the atmosphere with the exhaust gases. But it is poisonous, especially to children, harming the brain.

Tony Stone Photo Library, London

Some work environments can be bad for health. Miners, as well as workers in dusty factories, may develop respiratory diseases. Noise pollution from heavy machinery can damage the unguarded ears, and certain chemicals used in industry can cause skin cancer.

Many old buildings contain asbestos as a fire-proofing material. Only after some workers fell ill with asbestosis – a respiratory disease – did the harmful effects of this material become known. (Asbestos is still used in some countries in build-

Paul Raymonde

A red cast *over California at dawn – the effect of light being scattered by dust particles, air molecules and water droplets in the atmosphere. Large particles of pollution, or even large water droplets, can reduce the amount of blue light reaching the ground, so the sky appears yellow or even deep red.*

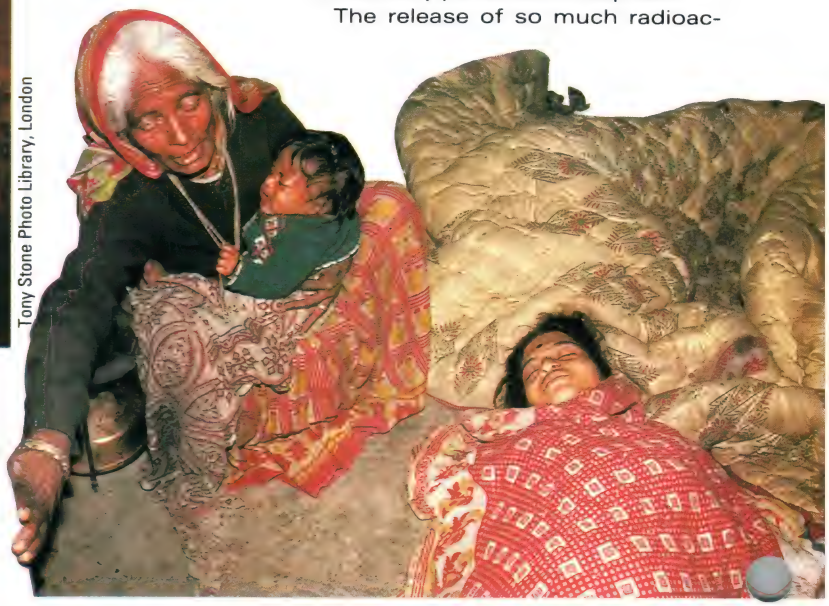
have been blinded and more are suffering from kidney failure.

A disaster of even larger scale was narrowly averted after a nuclear meltdown in 1979 at Three Mile Island in the USA. If this had not been contained, the entire populations of New York, Boston and Washington could have been killed.

Excess radioactivity

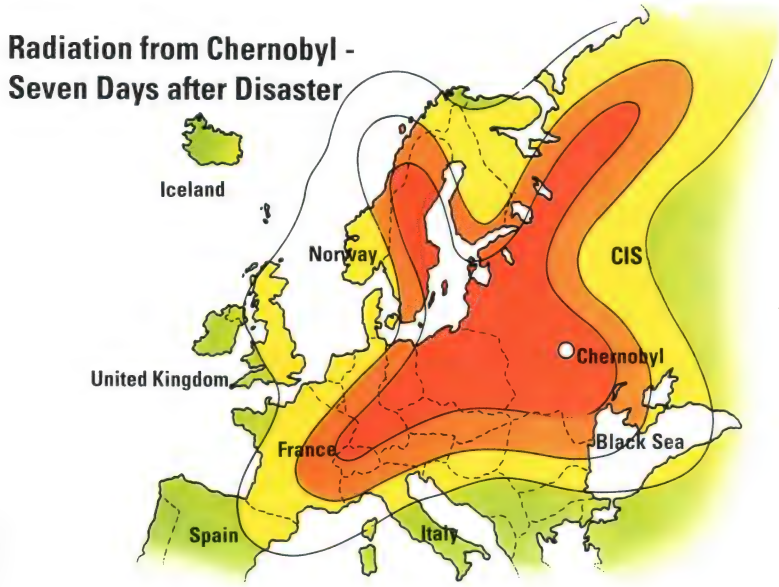
Accidents such as the Chernobyl disaster of 1986 in the Soviet Union – labelled the world's worst nuclear disaster – add more pollutants to the already polluted atmosphere.

The release of so much radioactive material into the skies affects both human and animal populations. A farm more than 50 km away from the reactor reported that, during the first nine months following the accident, 41 out of 87 pigs and 63 out of 350 cows were born with abnormalities. Some lacked heads, limbs, eyes and ribs; others had deformed skulls.



Tony Stone Photo Library, London

Victims of Bhopal *were blinded by the toxic gas that escaped from the chemical plant. Some suffered kidney damage.*



Chris Lyon

Radioactive debris *thrown up into the atmosphere after the Chernobyl disaster was carried huge distances by the wind – raining down on countries as far away as Britain and Sweden. (The heaviest concentration is the dark brown area on the map.)*

Gamma/Frank Spooner Pictures

Radioactive contamination *at the nuclear plant at Three Mile Island is expected to take 40 years to clean up and make safe.*

Alexander Tsiaras/SPL

ings; it is dangerous only when it breaks down and the fibres escape into the atmosphere.)

Pollution can threaten the lives of large numbers of people over wide areas. Large-scale evacuations were ordered by the Italian police in the neighbourhood of Seveso near Milan in July 1976 due to an accident at a chemical plant that released a small quantity of a weedkiller called TCDD into the air. The danger came from a by-product called Dioxin, which produces a blistering skin rash even in minute doses. Dioxin contamination may take many years to clear.

The appalling loss of life that can result from industrial pollution was made clear in the Indian city of Bhopal in December 1984. A leak of foul-smelling methyl isocynate gas from a storage tank at a Union Carbide Chemical factory killed at least 2,000 people. The gas has affected a further 200,000 – many

GLOBAL VILLAGE

- SUBVERSIVE VIRUSES
- COMPUTER VANDALS
- NETWORKS

ON THE EVENING OF 2 November 1988, thousands of computers ground to a halt across America. Internet, one of the world's largest computer networks, had been attacked by a computer 'virus'.

A virus is a sophisticated program that reproduces itself within the computer's own system, and spread from one computer to another with alarming speed. By the time this one had been destroyed, 36 hours later, the bill in computer 'downtime' (the time the system was out of action) had climbed to $100 million.

Growing concern

Happily this particular virus, planted by a student, was not intended to cause any lasting harm and did not eat up data. But it highlighted mounting concern about the security of giant computer networks around the world.

As more and more computers are linked together in what has been called the 'electronic village', the danger of attack grows. And it is not only programs like viruses that pose a threat. With secret defence plans and confidential information about companies and individuals routinely held on computer files, the risk of secret data being stolen is mounting.

Village voices

Two big technical breakthroughs made the electronic village possible. The first was the development of the modern phone system, which made high-speed communication possible between almost any two points on the Earth's surface. The second was the arrival of cheap, powerful, personal computers.

The ordinary phone system relays its electrical messages around the world by electric cable, fibre optics, radio waves and mirror waves relayed by orbiting satellites. It can also carry data between computers. This means that almost any home computer can be connected via the phone line – using a modem (short for modulator-demodulator) – to a global communications network and hundreds of thousands of other computers – home computers, desktops and huge mainframes.

The on-going installation of fibre-optic cable instead of ordinary copper ones in phone systems is accelerating the growth of these global communications. Fibre-optic cables are able to handle vastly more communications 'traffic' than copper ones of the same size: they can carry an astonishing 30 million characters – or the entire contents of a large encyclopedia – every second!

In the future every home and office will be linked into a fibre-optic communications network, in which large computers will act as exchanges, automatically directing messages at high speed to their

Ellen Schuster/The Image Bank

The world has shrunk, *electronically. Using a normal phone line and a computer, you can obtain information from huge, remote data bases on any subject – in seconds.*

British Telecom

Satellites *hover in the sky relaying phone conversations, computer data and fax signals. If you want to send money from England to Australia, it travels this way too. Billions of pounds are exchanged between banks by this method every hour of the day.*

destinations. In this lightning-quick network, two people located anywhere in the world will be able to use their personal computers to exchange text, drawings, photographs and film.

They will even be able to see and hear each other, using miniature TV cameras and colour monitors. All this fantastic range of sound, pictures and computer data will travel simultaneously along the same pathways through the same giant network.

One effect of the electronic village will be to make conventional offices obsolete. Instead of battling through crowds and traffic jams to get to work each day, more and more people will be able to do their work at home.

A personal computer, plugged into the worldwide communications network will allow employees to discuss plans, share ideas and attend meetings without ever stepping outside their front door. This will have a dramatic effect on cities – cutting the need for office space, relieving commuter congestion and allowing office workers to move further out into the countryside.

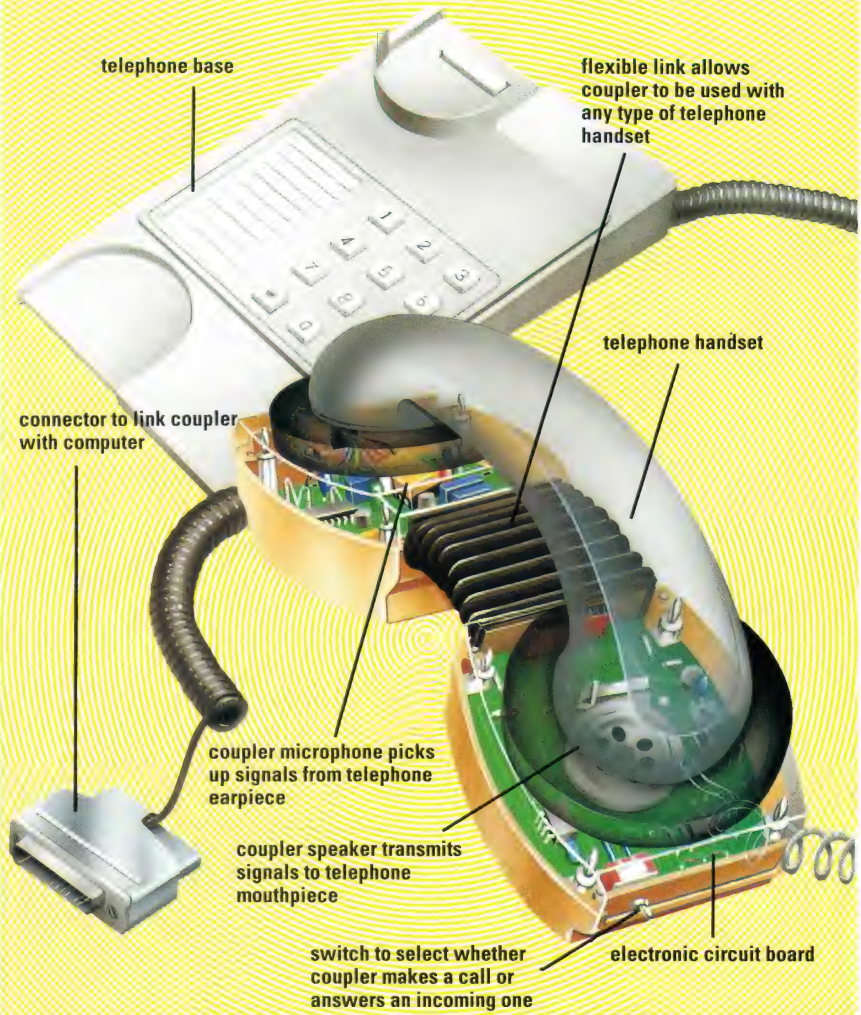
Personal papers

With every home connected to an increasingly powerful information web, our lives will change in other ways. There will be electronic newspapers personalized to each subscriber's taste. If your interests, say, are sport and foreign affairs, the electronic newspaper will scan the major reports coming in on

David Parker/SPL

Fibre optics *allow even faster communications. Huge amounts of information, travelling at the speed of light, can be carried down slender fibre-optic cables.*

MODEMS – CONNECTING TO THE WORLD



A modem is a device that sends data from one computer to another down the phone line. All information in a computer is stored as circuits switched on or off, equivalent to series of '0's and '1's. The modem takes these 'ons' and 'offs' and turns them into a series of high and low tones. These are sent down the phone line. At the receiving end, another modem converts these high and low tones back into 'ons' and 'offs'.

The simplest type of modem, known as an acoustic coupler, has rubber cups into which a standard telephone handset can be pressed. A small loudspeaker generates the stream of high and low tones into the mouthpiece, while a small microphone picks up the data stream from the earpiece. Many modems bypass the handset altogether and directly connect to the phone line.

Mark Franklin

these topics and then store them in your computer's memory. In the morning – or whenever you want to read your paper – a front page with crystal-clear graphics and colour headlines will pop on to your computer screen with articles on, say, the World Cup finals or kidnapping in the Middle East. To read the terrorist story, say, you just touch the head-

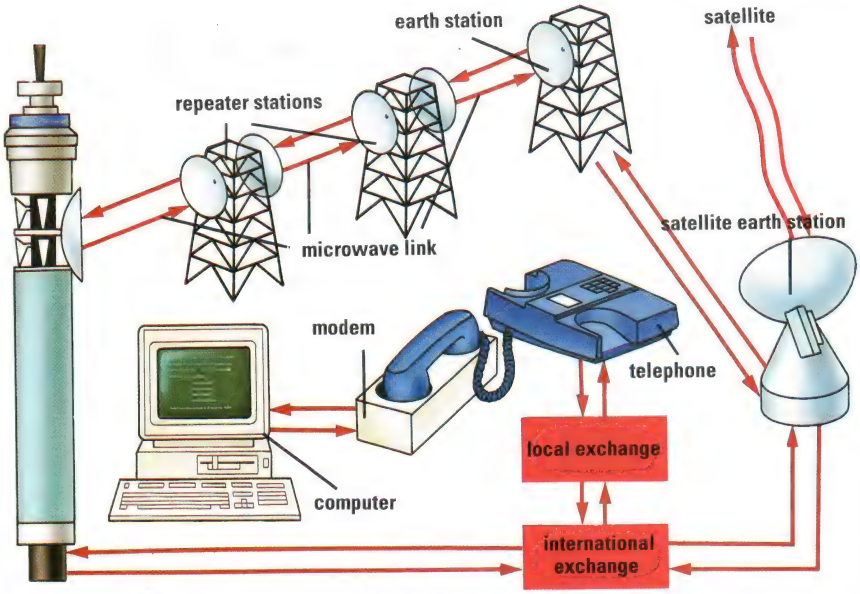
Ivaldi/Jerrican/SPL

The video phone *allows you to see who you are talking to. Ultimately, it will be 3-D, as if the caller were present in your room.*

line on the screen and all the details flash up. Thse may even include a TV interview with one of the hostages shown right alongside the computer text!

Banking, shopping, even attending school classes, can all be done without leaving your home, thanks to the electronic village. Already some banks offer their clients special home terminals where they can keep track of their accounts. Shops and ticket agents advertise through teletext services that appear on your TV screen.

Some of these services are connected to the phone line and are interactive. Punch in a credit card number and you can get goods delivered to your door or make a holiday or entertainment booking. And by getting into other huge commercial databases with your personal computer, you can track down information on virtually any subject.



John Houghton

Your phone connects *you to the world. Through microwave satellite links, you can speak to almost anyone on the planet. And if you couple up your computer via a modem, the world's data is yours to tap.*

Computer criminals

But all this sharing and availability of electronic knowledge has its dangers. The network is vulnerable to anyone who wants to misuse it – the hackers and the computer criminals.

The idea of a computer virus was first mentioned by David Gerrold in 1972 in his book *When Harlie Was One*, where a computer program called 'Virus' rings telephone numbers at random until it finds another computer. It makes a copy of itself in that new system, then both the parent program and the new copy start dialing again.

Evil geniuses

Today, fiction has become fact as hundreds of viruses invade millions of computers around the world each year. Most are planted by malicious programmers, called hackers, who purposely infect networks with viruses just for the fun of it. Usually the viruses only fill up unused storage space, without actually destroying data, though clearing up after them can still lead to extremely expensive delays.

As well as viruses, computers have been attacked by hostile programs known as worms, Trojan horses, and logic bombs! Trojan horses are viruses passed from

Simon Fraser/SPL

The photophone, *like the fax machine, sends pictures down the phone line. The images, though, are finely detailed and computer generated. In medicine, photophones may be used to get a second opinion.*

Just amazing!

ON ACCOUNT

STANLEY RIFKIN SWINDLED $10.2 MILLION – ALL AT ONCE – FROM A LOS ANGELES BANK'S COMPUTER SYSTEM BY GAINING ACCESS TO THE BANK'S TRANSFER SECURITY CODES.

Paul Raymonde

computer to computer, hidden inside a seemingly innocuous program and a logic bomb is a virus that waits for some specific event – Friday the 13th or the hard disc being half full – before it triggers.

Attacks on computers that control weapon systems could be especially dangerous. As a result, the United States Department of Defense has set up a Computer Emergency Response Team to guard its top-security networks.

Some companies, like FoundationWare in Cleveland, Ohio, now specialize in making vaccines – special counter-programs that will seek out and destroy future strains of virus!

In Britain, software companies have joined forces with computer users to fight electronic vandalism. Eventually, the new British group, called the Computer Threat Research Association, hopes to forge links with similar organizations in Europe and the rest of the world.

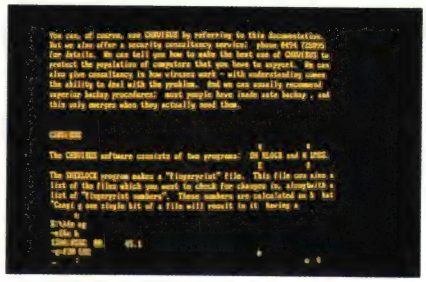
So far there are few countries where hacking has been made illegal. But if the spread of viruses continues, that will inevitably be the result.

Criminals who use computers to divert huge sums of money into their own bank accounts are already breaking the law, no matter how clever they think they are being.

But the worst threat comes from computer spying. There seems to be no foolproof security systems that can protect personal information, commercial data and military intelligence on computer.

Jerry Mason/SPL

***Computer viruses** have already hit NASA. Imagine the chaos if the computer was attacked during a mission.*



Jerry Mason/New Scientist

***A computer virus in action.** This one makes letters fall off the screen, one by one, until they are all in a jumbled heap along the bottom*

INTO THE FUTURE

SHRINKING WORLD

Joe Lawrence

▲ *Next century, it may be unnecessary to go out of your front door. Children the world over could be taught in a huge electronic classroom via interactive TV.*

▲ *Mail and newspapers will be delivered electronically. Banking and shopping will be done from home. Voice-print identification will act as a signature.*

▲ *Videophones will present moving, lifelike, 3-D holographic images, and the telephone will automatically translate for you if the caller speaks a different language.*

NATIONAL SECURITY

- BORDERS
- REFUGEES
- RADIO JAMMING

THE SECURITY OF ITS OWN country's borders is of vital interest to any government. Borders that are not fixed and settled are a major cause of wars. And the flow of arms, drugs, crime and illegal immigrants across international borders is a major cause of internal strife.

Most borders have been in place for hundreds of years. They often follow natural geographic barriers – such as seas, rivers and mountain ranges – and mark a clear cultural or political difference between the people on either side. The French live on one side of the Pyrenees, for example, the Spanish on the other.

Cause of strife

Other borders have come about because of conquest, colonization or political expediency. This has left some countries in dispute over just where one begins and the other ends.

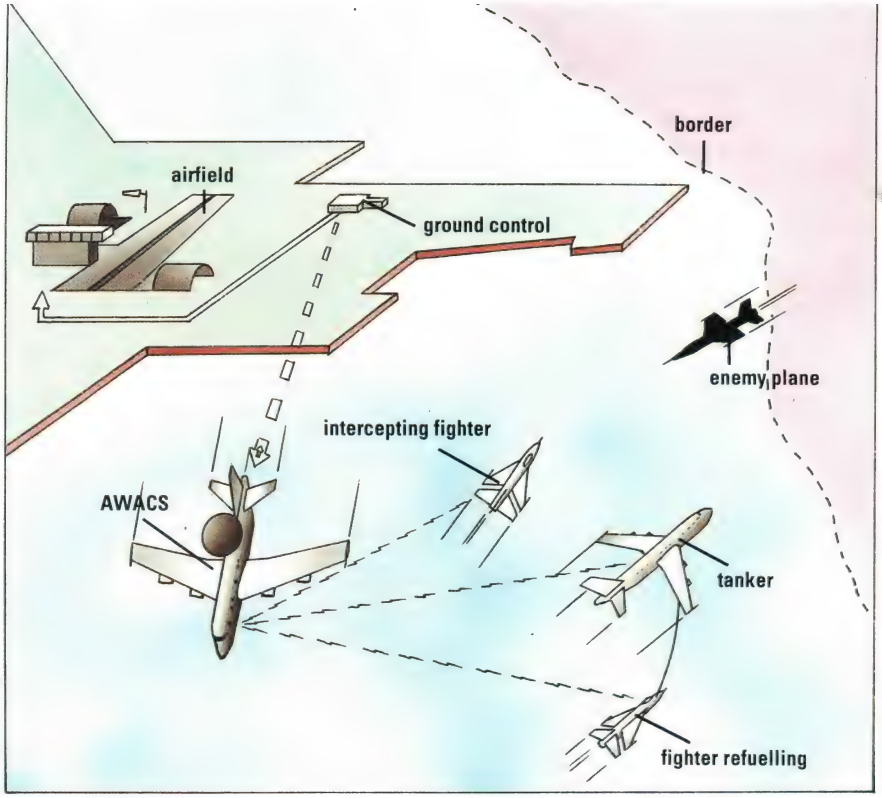
Iran and Iraq fought over the Shatt al-Arab waterway since 1980. And in 1974, some Cypriots of Greek descent wanted the Mediterranean island of Cyprus to become part of Greece, so the Turkish army invaded the northern part of the island to protect – as they saw it – the rights of Cypriots of Turkish origin.

Troubled times

Some Irish feel that Britain has no right to any part of the island of Ireland, while others – largely those in the north of British origin – feel that although many of their ancestors came as settlers in the wake of conquering British armies, they have been there a long time and have as much right to be there are anyone.

In the past, huge barriers have been built to keep warring peoples apart. The remains of the wall built

***Checkpoint Charlie** was one of the few places people could cross the Berlin Wall during the Cold War period.*



Matthew White

***Huge AWACS aircraft patrol** nations' frontiers. Loaded with airborne warning and command systems, they detect incoming enemy planes and dispatch friendly fighters to intercept them. Fighters on patrol are kept ready at all times by refuelling them in the air.*

by the Roman Emperor Hadrian can be seen in Northumberland in the north of England. Hadrian had the 113 km wall built to keep marauding Pictish tribesmen, who lived in what is now central Scotland, out of the Roman province of Britain.

The Romans built other walls along the River Rhine and River Danube to keep back the 'barbarians'. But none of these compares with the Great Wall of China. Built on the orders of Emperor Shih Huang Ti to keep out the Huns, the Great Wall stretches over 2,000 km around the northern border of China. It is probably the largest building project ever undertaken.

In more recent times in Europe a wall was built in Berlin, part of a massive defensive frontier which stretched across Europe from the Baltic Sea in the north to the Adriatic Sea in the south. This so-called Iron Curtain was made up of vehicle traps, minefields, barbed-wire fences and watch towers designed to stop people in Eastern Europe reaching the West. This frontier largely followed the line where the armies of Britain, France and the USA met those of the Soviet Union after Germany had been defeated at the end of World War II.

Germany was divided into two – West Germany and the communist East. The country's capital, Berlin, and the eastern part of the city became the capital of East Germany. West Berlin soon became a magnet for people trying to escape from Eastern European countries.

Despite all their efforts, the Soviet Union and East Germany could not prevent large numbers of people sneaking through into Berlin and escaping to the West. So in 1961, they built a wall across the city. Completed very rapidly, this structure became a grim symbol of the division of the world into capitalist and communist nations.

Glasnost

In the late 1980s new atmosphere of openness – or *glasnost* –in Eastern Europe, countries such as Hungary started to dismantle their border defences. And in 1989 The Berlin Wall itself was broken up.

While in one part of the world, barriers have been coming down, in another – North Africa – they have been raised up. In 1975, the former Spanish colony of Western Sahara was invaded by Morocco who claimed that it was part of their country. Local resistance fighters, the Polisario guerrillas, began to wage a war against the occupying Moroccan forces from bases across the border in Mauritania.

Sand wall

In 1980, in an attempt to stop the guerrillas infiltrating across the border the Moroccans began building a huge sand wall extending out into the Sahara and covered with people-sensing equipment (unattended Ground Sensors or UGS) developed by the Americans during the Vietnam war.

Meanwhile, the USA is building its own fences at home now, this time along its border with Mexico. Huge numbers of illegal immigrants trying

Gamma/Frank Spooner Pictures

Gamma/Frank Spooner Pictures

***The border** between communist North Korea and capitalist South Korea. In Europe, the Iron Curtain marked the same ideological border. Communist troops (inset right) look out on the capitalist West.*

Rex Features Ltd

Ric Ferro/Black Star/Colorific!

In the 1980s *Vietnamese boat people left their homeland in millions. They set out across the South China Sea in small boats, braving typhoons and pirate attacks.*

Gamma/Frank Spooner Pictures

Cuban refugees flee *the communist regime of their island home in the hope of finding a better life in the USA, but many end up in slums.*

Special riot squads *protect national borders internally, too. Here, French riot police fight Corsicans who want their island to be independent.*

to escape the poverty, political repression and guerrilla warfare of Central and South America try to cross the Rio Grande from Mexico into the United States each year, in the hope of finding a better life.

In an attempt to stem this flow, the USA has built huge fences along its southern flank. However, the border is still impossible to police thoroughly. In some places, for example, people cross the border each morning and evening on their way to and from work, and it is impossible to check every car in the rush-hour traffic. In addition, the border itself is 2,500 km long. Every night illegal immigrants cut their way through the fences and cross into the USA.

Drug smuggling

America has another problem on its southern border – drug smuggling. Airborne patrols with sophisticated tracking equipment search for the light planes and small boats that bring in the drugs from Latin America.

The United States is not the only country that suffers from the problems of illegal immigration. Hong Kong, Singapore, Malaysia, Indonesia and Thailand have all been plagued by millions of people fleeing poverty or fighting in the communist regimes of Vietnam, Laos and Cambodia.

Governments not only try to stop people and drugs crossing their borders, they also try to control technology and information. For instance, the US government has banned certain computer equipment being sold to unfriendly powers.

Some countries try to jam radio signals coming from outside by broadcasting jangling sounds on the same frequency as external radio stations. The former Soviet Union jammed Western broadcasts for years, but gave up in the 1980s.

Air and sea

A country's borders also extend up into the air above. Some countries prevent any international airlines flying over their country. Most prevent foreign planes flying over sensitive military establishments. And when planes land, the passengers are checked by customs officials to ensure that they are not intending to settle in the country illegally and to make sure that they are not bringing in drugs, firearms, illegal goods or infectious diseases.

Borders also extend out into the sea. By international agreement, a country controls a 19 km strip of water around its coasts. Some countries have tried extending this limit to protect fish stocks. This has sparked 'wars' between fishermen and navy patrol boats.

Steven B Williams/Image Bank

The Great Wall of China *was the biggest building project ever undertaken. It defended China's northern border from hordes of marauding Huns.*

Takeshi Takahara/SPL

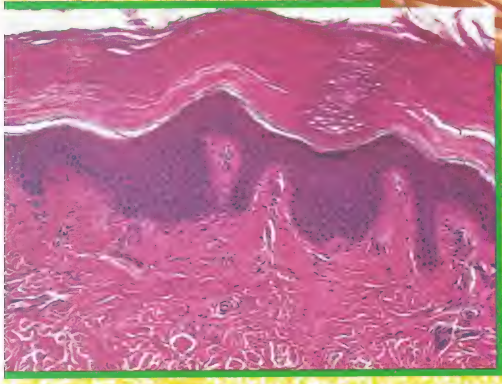
Water skiers *speed across the boundary between air and sea.*

The boundary layer *is the air that hugs a streamlined form. Where the white tapes drop, the boundary layer has separated causing turbulence and drag.*

Jean Marc Barey/Vandystadt/Allsport

Skin is the boundary *between you and the outside world. It keeps the insides in and the outsides out. Under the skin, the white boundary (inset) separates the skin from the flesh.*

Martin Dohrn/SPL



When you play a game *– cricket, football, rugby, basketball – there is a boundary around the pitch that marks the limits of area where play is allowed. There are also inner boundaries.*

Astrid & Hans Frieder Michler/SPL

Tony Stone Photo Library, London

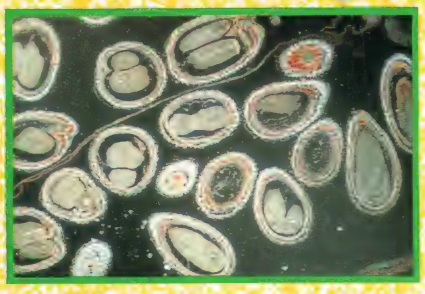
ZEFA

NASA/SPL

Some patients *need an extra boundary between them and the world to keep harmful germs or substances out.*

Tiny cells *need a boundary or membrane to separate their internal fluid from the external fluid they float in.*

In a hot air balloon*, the surface of the balloon marks the boundary between the hot air inside and the cold air outside – the difference in temperature makes it fly.*



Robert Harding Picture Library

ZEFA

The blue boundary *of the Earth's atmosphere is visible from Space – although it looks red when the sun is rising or setting behind it.*

TO THE EARTH'S CORE

A JOURNEY TO THE CENTRE of the Earth from the surface at the Equator to the very core itself would take you through an incredible 6,367 km.

The surface of the Earth, a rough, and wrinkly skin of mountains, hills and valleys, is known as the crust. It is a relatively thin layer of rock, soil and water which can range from being more than 60 km thick in the great continental areas to a mere 4 km depth beneath the sea bed. Granitic rocks rich in silicon and aluminium form the continents. Below the continents and the oceans is a layer of basalt. This strong, shell-like outer crust, together with the layer immediately below it, 'floats' on top of a softer shell of molten rock – magma.

***A limestone cave** in South Wales. Most of Britain's limestone was laid down in the Carboniferous period, 345–280 million years ago.*

Chris Howes/Planet Earth Pictures

Going deeper

Below the crust there is a layer of rock known as the mantle, which is about 2,900 kilometres thick and consists mainly of a dense, dark mineral called oviline.

Still deeper is a layer known as the outer core, more than 1,255 km deep, where the iron and nickel within have turned into a gigantic molten mass. The temperature at the inner core, thought to be made of solid iron and nickel, is estimated to be 4,500°C. At the centre, each side of a cube of matter measuring 2.5 by 2.5 cm is under 20,000 tonnes of pressure.

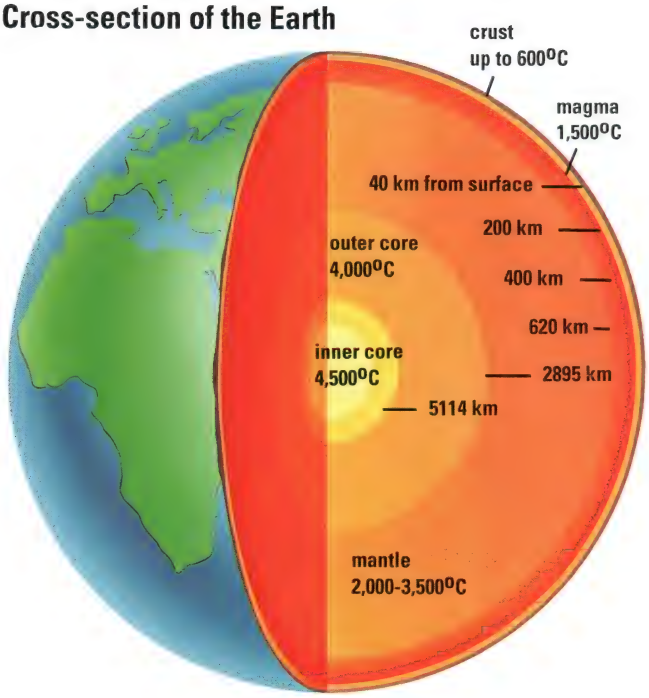
How do we know what is below the Earth's surface? It is very difficult to drill down more than a few kilometres because the farther

PROFILE

VITAL STATISTICS OF THE EARTH

Age	about 4,600 million years
Weight	about 6,000 million million million tonnes
Diameter from Pole to Pole	12,714 km
Diameter at the Equator	12,757 km
Circumference around the Poles	40,020 km
Circumference around the Equator	40,075 km
Surface area of the land	148,328,000 sq km
Largest single land mass (Eurasia)	53,698,000 sq km
Surface area of the oceans	361,740,000 sq km
Total surface area	510,065,600 sq km
Volume of the oceans	1,285,600,000 cubic km
Total volume	1,083,207 million cubic km
Highest point (Mount Everest, Himalayas)	8,884 m above sea level
Lowest point (Marianas Trench, Pacific Ocean)	11,034 m below sea level

Cross-section of the Earth



Matthew White

***The Earth** is like an onion – a cross-section would reveal a number of layers. Below the crust, the mantle is made of magma – extremely dense, semi-liquid rock. The pressure at the central core is so great that the rock must be solid. Temperatures are estimated.*

down you go, the higher the temperature and pressure. It has been said that a city on the Moon could be built more easily than a house 25 km below the surface of our own planet.

Volcanoes have provided clues to the structure of the lower crust and the mantle; geologists analyse rocks, lava (molten rock) and ash thrown out through a volcano's crater from deep beneath the Earth's surface.

Shock waves

The technique that reveals most about the structure of the Earth is reflection seismology. In this technique, artificial shock waves created on the Earth's surface are reflected back from rock layers deep within the crust. The way these reflected shock waves behave is picked up by sensitive detectors called geophones. By moving the detectors around and taking a variety of readings, a detailed computer-generated, three-dimensional image of the Earth's crust can be built up. Petroleum geologists have used this method to detect major oil and gas fields.

Another way to find out what is underground is to go down and explore via a cave. The study and exploration of caves – natural underground cavities – is called speleology.

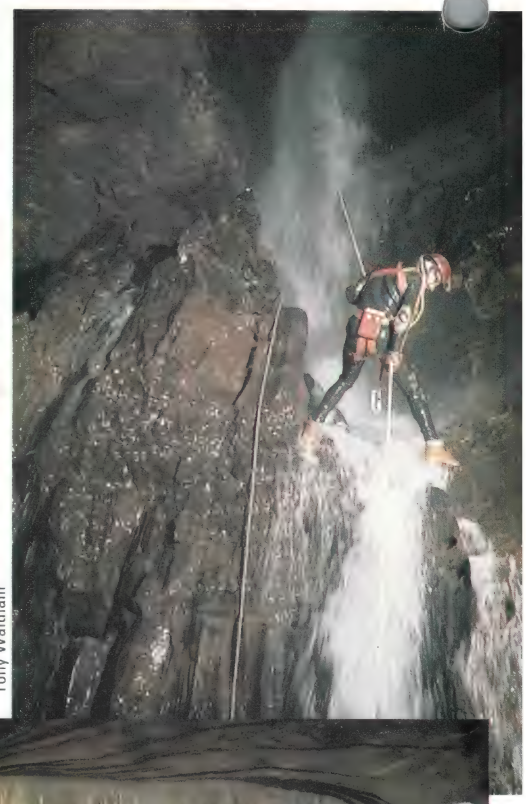
Water action

Sea caves are excavated when waves beat upon weak places in a cliff. Tectonic caves are formed when layers of rock separate or crack. Such caves usually have narrow openings called fissures.

A lava flow, pouring out of a volcano, cools and solidifies first on the top, bottom and sides. Then the liquid in the centre may drain away, leaving a cave. As a lava cave is very close to the Earth's surface, it is easily eroded. Lava caves are usually found in recent lava flows – recent meaning less than 20 million years old.

Many caves are created by the action of underground water. The water wears away at cracks in the rock, excavating whole subterranean systems of caves, fissures and pot-holes (deep cylindrical holes). The Mammoth Cave system in Kentucky, USA, is the world's most extensive network. It and the neighbouring Flint Ridge system together have over 530 km of mapped passageways. Cave systems are often found in layers of limestone. This is because water containing dissolved carbon dioxide from the atmosphere and soil above slowly wears away the limestone.

If the water table lowers, the



Tony Waltham

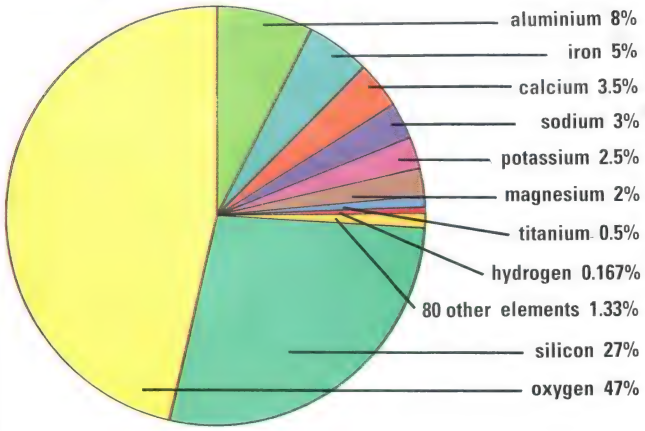
***A 'spelio'** – a caver – abseils down a 30-metre waterfall in the Diccan Pot cave system under the Yorkshire Dales of north-east England.*

Gamma/Frank Spooner Pictures

Chris Howes/Planet Earth Pictures

***Stalactites** in an underground cave resemble a curtain of icicles. A straw stalactite (right) has the diameter of a drop of water. Evaporating water leaves a deposit that slowly forms a stalactite.*

What is the Earth's Crust Made Of?



Mark Franklin

The crust *of the Earth is made of basic substances called elements. Almost all the rocks in the crust are made from just eight of these elements.*

Cave diver *Kurt Amsler carries his own oxygen supply as he explores a sump – a passage filled to the roof with water.*

Kurt Amsler/Planet Earth Pictures

water in the cave system drains away, allowing air to fill its place. The water does not disappear completely – making its way down from the ground surface to the water table below, it runs through underground caves in streams and waterfalls. Where its passage is blocked, it accumulates in underground lakes.

Stalactites

Water dripping from the roof of a limestone cave is saturated with calcium bicarbonate. As each droplet falls, some of the water evaporates, leaving a tiny amount of calcium carbonate behind. Gradually a calcium carbonate 'icicle' grows down from the roof. This is called a stalactite. Water that drips on to the floor deposits calcium carbonate in the same way. A mound that looks like an inverted icicle develops. This is called a stalagmite. Sometimes a stalagmite grows to meet a stalactite hanging from the roof to form a single column.

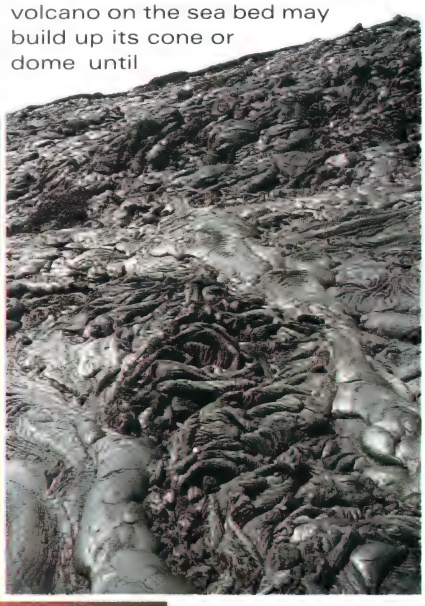
ZEFA

A volcano is a fissure or vent (pipe-like hole) from which solid rock, lava, gas and ash erupt on to the Earth's surface. The Earth's crust and upper mantle are divided into plates, which float on the magma below. Unstable zones exist where two plates meet. It is here that most volcanoes occur.

Volcanic islands

Volcanoes are often shaped like cones or domes. A cone is formed from ash and stiff, viscous lava that cools into rock fragments. A dome is made up of fluid lava that has now cooled into a solid mass. A volcano on the sea bed may build up its cone or dome until the top projects above the sea. Many islands are actually the tips of volcanoes: 90 per cent of the two Hawaiian volcanoes, Mauna Loa and Kilauea, are under the sea.

In some volcanoes, such as Mount Fujiyama in Japan and Tenerife's El Teide, escaping gases force out a huge and spectacular cone-shaped plume of smoke which contains ash, cinders and large lumps of rock. Other volcanoes may look like quiet lakes, such as those in Bolzena and Laziale, Italy, but are in fact volcanic craters filled with water during a 'resting period' between eruptions that may last as long as 20,000 years.



Philip Chapman/Planet Earth Pictures

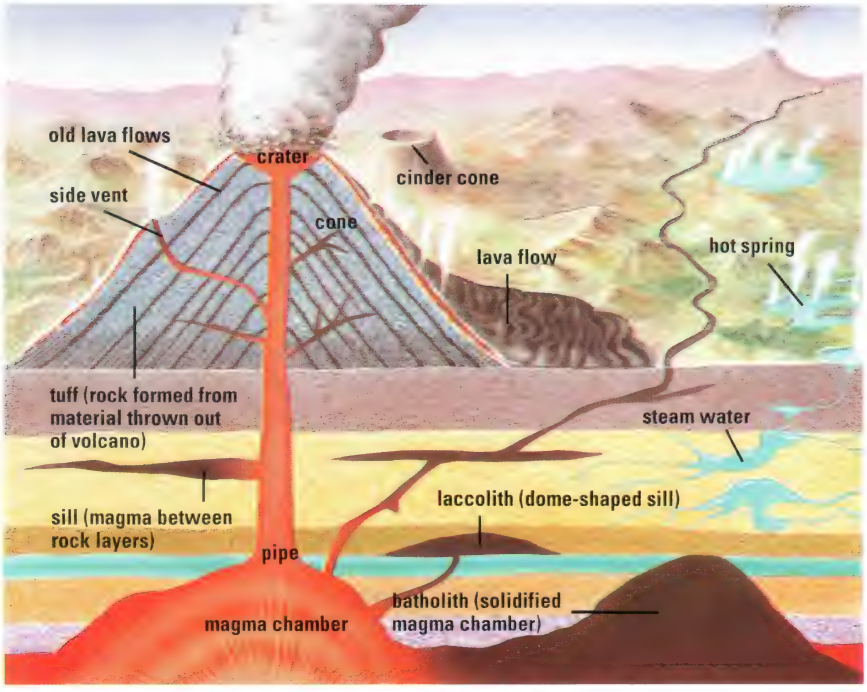
Science Photo Library

El Chichon *volcano in Yucatan, Mexico, after eruptions in 1982. A sulphur-laden plume of ash was hurled 16.8 km into the atmosphere.*

Kilauea *is one of the two active volcanoes on the 'Big Island' of Hawaii. Since 1983, massive amounts of magma have burst through to the surface, emerging as highly fluid lava that flows down the side of the volcano and hardens into rope-like coils.*

Lava flows

There are also volcanoes simply made up of cracks in the ground that release glowing hot lava flows, which can consume local villages and devastate the countryside.



John Carty

***Volcanoes** are like safety valves in the Earth's crust. When the pressure of the magma exceeds that of the rock above, it shoots to the surface.*

Lava flows are common on Hawaii and also in Iceland.

Volcanoes are classified into five main types:

- *Hawaiian* volcanoes emit lava from far below the Earth's crust. It pours down their sides, which have broad summits built up from layers of cooled lava and ash. Hawaiian volcanoes are particularly noted for their spectacular fire fountains, which leap high into the air
- A *Stromboli* volcano's lava comes from within the crust. This lava is not as fluid as that from a Hawaiian volcano and is often held under pressure until, in bursts, lava and glowing ash explode out of the crater into the air.
- *Vulcanian* volcanoes are under even higher pressure and have more powerful eruptions, throwing out huge rocks within dense clouds of ash and cinders that fall back on the volcano, building up a steep cone
- The most explosive of them all is a *Plinian* volcano – so explosive that the cone may collapse in on itself
- A *Pelean* volcano throws out a cloud of ash and hot gas, which then roll down the side of the mountain in a glowing avalanche.

Darkening skies

Thirty four died in 1980, when Mount St Helens, a long-dormant volcano in the north-western corner of the United States, erupted. The explosion blew the top off the volcano, creating a 20,000-metre column of ash so dense it darkened the skies some 250 km away at Walla Walla.

Fumaroles are openings in the ground in volcanic areas, through which steam and gases escape, carrying dissolved elements and compounds such as sulphates, chlorides, sodium and iron. Mineral deposits, for example sulphur crystals, collect around the fumarole. On Mount Erebus in the Antarctic, steam has frozen around the fumaroles, creating spectacular ice chimneys 20 metres high.

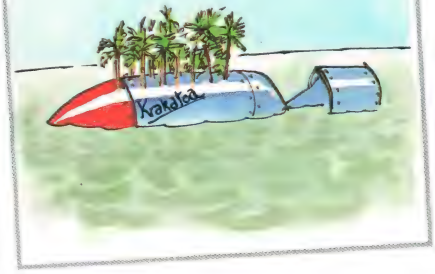
Fountains of steam

A hot spring is similar to a fumarole, but contains much more water, which comes from underground water running through cracks in the rocks. A geyser is a spectacular fountain of hot water and steam that shoots into the air. It is named after the 'Great Geyser' of Iceland which was active for more than 350 years, until the 1930s. The water can be well above boiling point.

Just amazing!

MEGA-BLAST

THE ERUPTION OF KRAKATOA IS STILL THE GREATEST EXPLOSION EVER RECORDED. THIS VOLCANIC ISLAND IN INDONESIA WENT UP IN 1883, WITH 26 TIMES THE POWER OF THE LARGEST H-BOMB EVER TESTED.



Paul Raymonde

***Wide cracks** appeared in the main road of La Reunion, an island in the Indian Ocean, when La Fournaise, the island's volcano, swelled before erupting violently in 1986.*

Gamma/Frank Spooner Pictures

NUCLEAR TESTS

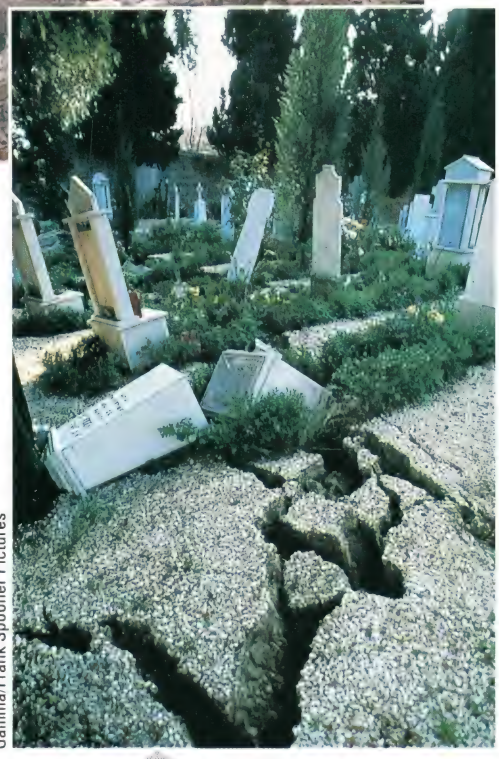
It is much safer to test a nuclear bomb by exploding it underground, rather than on the surface. The Nevada Test Site is an 320,000 hectare site in the desert 104 km north-west of Las Vegas. Working from a tower, scientific instruments are mounted into a canister, which is lowered underground, with the weapons canister. Cables send information from the instruments underground to monitoring equipment in trailers on the surface. In the 1980 Huron King nuclear test, pictured here, a crater 100 metres wide and 30 metres deep was created by a nuclear device detonated 300 metres below ground.

US Department of Energy

US Department of Defense

EARTHQUAKE!

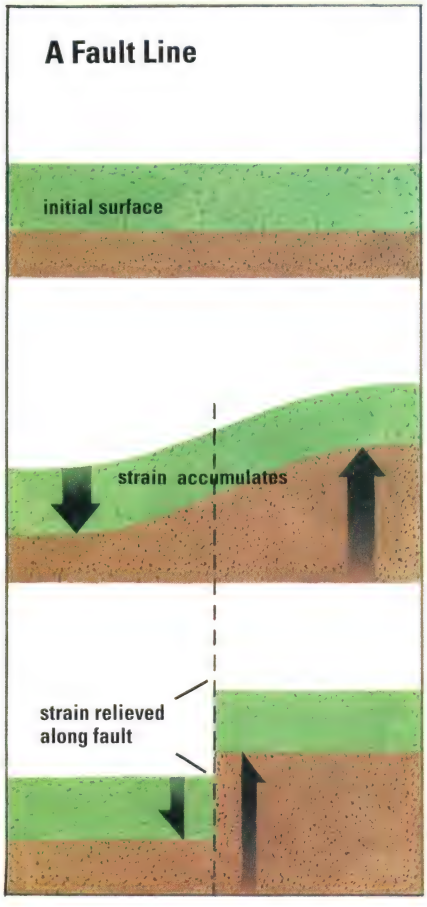
Gamma/Frank Spooner Pictures



Gamma/Frank Spooner Pictures

The devastation *caused by an earthquake can range from cracks in the ground to the full-scale destruction of buildings, as in Armenia (top).*

- SHOCK WAVES
- SEISMOGRAMS
- RICHTER SCALE



Caroline Brodie

The Earth's crust *will bend only so far, under the pressure caused by plates colliding. Then it will snap along a fault line, sending out shock waves.*

THE GROUND BENEATH YOUR feet begins to vibrate violently. Walls shake, the ceiling cracks and windows shatter. Loose objects are overturned. A loud rumbling tells you that you are caught up in an earthquake. If you are lucky, the tremor will pass without major damage.

But earthquakes can sometimes be devastating in their effects. Whole towns, and even regions, have been flattened. Cracks in the ground swallow up buildings. Fires and floods may follow, and tidal waves may cause large-scale flooding. The worst earthquakes have claimed hundreds of thousands of lives and caused untold misery.

Long or short

Most earthquakes last for less than a minute, but in 1966, an earthquake in Tashkent, USSR, lasted for 38 days! Fortunately, earthquakes on this scale are very rare. Of the million or so earthquakes every year, only about a thousand are ever felt on the surface and only a few cause any damage. Many are under the sea, or so tiny that they can barely be detected.

Earthquakes are the result of severe shock waves passing through solid rock in the Earth's crust. These occur when layers of rock are gradually stretched or compressed so that they deform into basins or folds. If the strain is sudden or too great, the rock may fracture and shift abruptly. At one end of the scale such rock movement may have a relatively small effect, such as when rocks collapse over a cavity, or gravitational forces on a cliff edge cause an avalanche.

The more violent earthquakes, which present a threat to life and property, are caused by movements of the Earth's tectonic plates. These plates, which lie underneath the major continents, are constantly moving very slowly. In places where

two plates push or slide against each other, stresses build up in the rock. The rock will change shape to a certain degree, but when it reaches its limit, it breaks at the weakest point, creating a 'fault' line and sending shock waves to the surface. The shock – or seismic – waves travel outwards from the centre of the earthquake, known as the focus. The focus is often deep in the Earth's crust, and the point on the surface immediately above it is called the epicentre. When the earthquake occurs very deep in the Earth there may be no surface displacement.

Secondary effects

However, as the shock waves hit the surface, huge ripples may spread across the land, which may bulge and crack and close up again. The land waves which occur close to the epicentre can trigger off rockfalls, landslides and avalanches which can cause as much damage as the original earthquake. The secondary effects of an earthquake may be collapsing buildings, ruptured dams, gas or water pipes and the consequent fires and floods.

Earthquakes can also generate huge sea waves known as tsunami. Produced by displacement in the ocean floor, they can cause large-scale devastation. Although they may be only half a metre high out at sea, they build up to great heights as they reach the coast, where they do most damage. In 1958, a tsunami some 30 metres high hit the Alaskan shore at more than 200 km/h and destroyed large areas.

With earthquakes causing so much damage and suffering, it is important to try to predict when and where they will take place.

Animal behaviour is one way of predicting an earthquake. Just before the onset of an earthquake, dogs sometimes howl, rats have been seen to leave their holes and birds may become restless. In 1976, the people of a Chinese city noticed this strange behaviour and evacuated the city hours before an earthquake reduced it to rubble.

However, there are more scientific clues to an impending earthquake. Just before rocks break apart, their crystal structure may open and close, releasing radon gas into groundwater, which is carried into wells. Monitoring wells may thus give notice that rocks are about to give way.

There are also electrically charged gases which are sometimes released and these produce the faintly-glowing 'earthquake lights' that are occasionally reported. Recently, scientists have also shown that surges of hydrogen, up to ten times higher than normal, can be detected above fault lines prior to an earthquake. None of these effects is common to all earthquakes and so several techniques have been developed to provide a more accurate prediction.

Strain gauges in fault lines (giant cracks that may run for kilometres below or across the Earth's surface), can detect the build up of stress levels. Tiltmeters, sophisti-

Universal/Kobal Collection

***Flooding** can be as destructive as quakes. In this scene from the film 'Earthquake', a dam has burst, and sent millions of tons of water crashing down the hillside, wiping out the houses on the hill below.*

Gamma/Frank Spooner Pictures

***Dogs are invaluable** for tracing victims buried alive under the rubble caused by earthquakes. After the Armenian disaster of 1988, survivors were still being found up to a week after the quake. Soviet authorities stopped clearing the flattened area until they were certain that all survivors were safe.*

BURIED ALIVE

David Leah/Science Photo Library

Rex Features

When Mexico City was struck by an earthquake measuring 8.1 on the Richter scale in 1985, many people were trapped in the rubble of collapsed buildings. The Special French Disaster Squad was flown in to help dig out survivors, using cranes and heavy machinery, and on September 23, they rescued Leonardo Ventura Lopez. He had been buried alive for five days under the rubble of the Juarez Hospital, which was destroyed in the quake. When he was brought to the surface, he shouted out; "Vive la France!" in honour of his rescuers.

PROFILE MAJOR FAULT LINES OF THE WORLD

Mark Franklin

Worst ever earthquakes
(with estimated number of deaths)

856	Corinth, Greece	45,000
1201	Mediterranean coast	1,100,000
1556	Shensi, China	830,000
1703	Edo (now Tokyo)	200,000
1755	Lisbon, Portugal	650,000
1923	Kwanto, Japan	140,000
1935	Kansu, China	100,000
1950	Assam, India	60,000
1971	Yungay, Peru	50,000
1976	Tangshan, China	650,000
1985	Mexico City	10,000
1988	Spitak, Armenia	50,000
1993	Killari, India	10,000

cated versions of the carpenter's spirit level, have a bubble whose movement detects any movement of the Earth's surface. Creepmeters – wires stretched across a fault – show up any sideways movement.

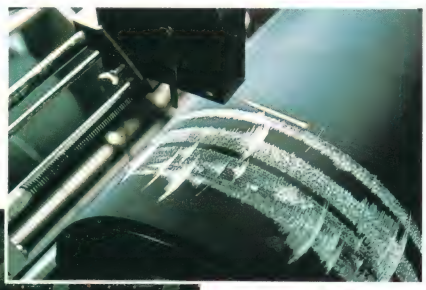
Seismology

However, the most scientific type of earthquake prediction is carried out by seismologists using a seismograph. This highly sensitive instrument can detect small shocks from below the Earth's surface. The small vibrations detected are converted into an electrical current which is amplified and traced on a highly sensitive chart recorder. In this way, the sudden release of stress in rocks which precedes an earthquake can be detected. Where seismographs are left in remote areas and daily readings are not possible, the data can be transmitted to a central station.

A recent technique for monitoring Earth movement involves using satellites to send signals to different fixed Earth stations. The signal network makes it possible for the satellite to pick up information revealing whether the stations have moved position relative to each other.

Seismographs measure the intensity of an earthquake in terms of the energy released and the subsequent vibration caused, and the Gutenberg-Richter scale is used to define this energy. This scale – usually just called the Richter scale – is mathematically linked to the readings on the seismograph in a formula devised by Dr Beno Gutenberg and Dr Robert Richter in 1935. An earthquake measuring 2 on the Richter scale represents the smallest shocks causing slight damage; 6 relates to substantial damage, and 8.9 is the highest reading ever obtained. Few earthquakes exceed 8, but, on average, there is one of these somewhere in the world each year.

Another method of measuring earthquakes is the Mercalli scale which describes what people see or feel during an earthquake. There are several types of such scales which range in observation from small vibrations which cause objects to fall off shelves, to major shocks.



USGS/HVO

Gamma/Frank Spooner Pictures

Seismograms – *appearing as waves on a chart (above) – predict earthquakes by sensing vibrations in the Earth's crust.*

Armenian tragedy

On December 7, 1988, an earthquake near the Turkish border in Northern Armenia measured 6.9 on the Richter scale. It wiped the town of Spitak from the face of the Earth. In Leninakan, (now Kumayr) more than three quarters of the apartment blocks collapsed completely, burying many people with them. The earthquake happened so fast that pigeons sitting on ledges were killed outright, and people died at tables without having a chance to get up.

Other towns near the earthquake suffered similar devastation. More than 50,000 people died as a result

of the earthquake, which occurred in one of the world's most intensely folded and active regions, the Lesser Caucasus Mountains of Armenia, Georgia and Azerbaijan.

International rescue teams were flown in from 70 countries to help with a massive relief operation, which was not helped by the bitterly cold weather. Five thousand people were dug out of the rubble alive in the first two days, and survivors were still being pulled out a week later. One woman told how she kept her four-year-old daughter alive by slicing her fingers so the girl could drink her blood while they were buried alive for eight days.

In terms of death toll, the worst recorded earthquake in history was on January 23rd 1556, when around 830,000 people died in the Chinese province of Shensi. These figures are certainly more reliable than the estimated death toll of over one million in July 1201, when a massive earthquake devastated cities on the eastern Mediterranean coast and the Near East.

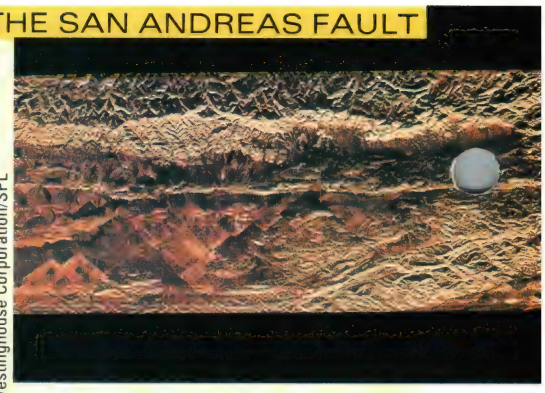
More recently, in 1976, China suffered a similarly devastating earthquake in the heavily populated industrial city of Tangshan where more than 650,000 people died. The Chinese capital of Beijing (Peking) was more than 100 km away but still sustained damage to property.

When it comes to measuring the strongest-ever earthquakes, the Richter scale is limited in its use. Since 1977, the Kanamori scale has been adopted to measure the energy released during the strongest earthquakes. The most massive quake recorded by any electrical instrument was at Lebu, Chile in May 1960, which measured 9.5 on the Kanamori scale. But this rates only 8.3 on the Richter scale.

Seismologists have predicted that disastrous earthquakes will be more frequent in the future, because over one-third of the world's largest and fastest growing cities are located in high risk areas. It has been estimated that by 2035, more than 600 million people will be living in major cities within 200 km of tectonic plate boundaries.

David Parker/Science Photo Library

THE SAN ANDREAS FAULT



Westinghouse Corporation/SPL

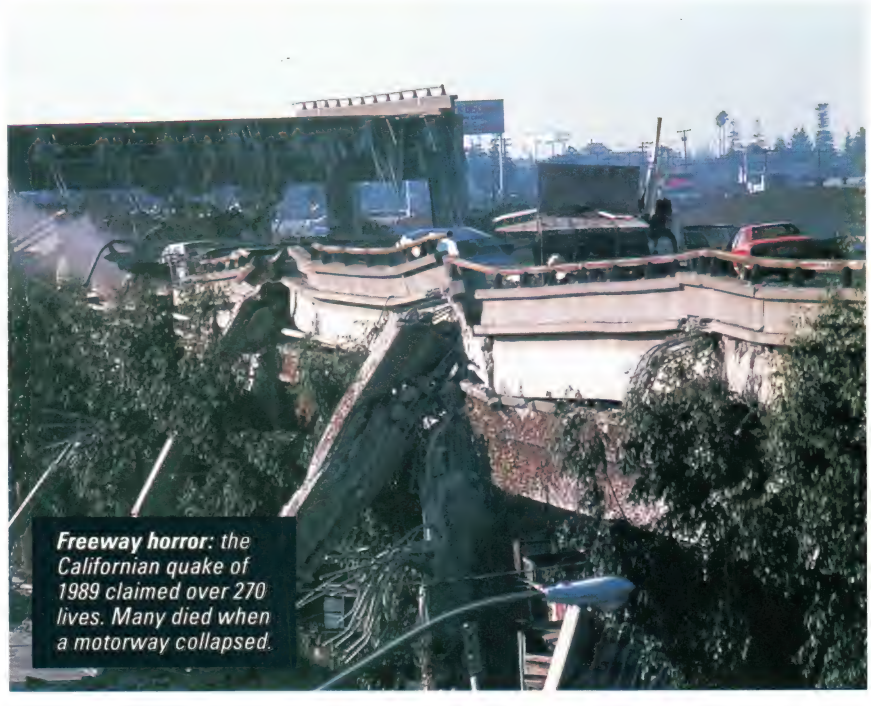
The most famous fault complex in the world is the San Andreas fault, in California. It lies on a point where the Earth's crust on the western side of the fault is sliding north-west, while the crust on the eastern side is sliding south. American scientists have shown that the rate of slippage over the past 13,000 years has been an average of 36 millimetres a year.

The most severe earthquake along the San Andreas fault occurred in 1906 when a quake lasting less than a minute reduced San Francisco to ruins, causing $1,000 million of damage and killing 700 people.

The Los Angeles earthquake of 1994 measured 6.8 on the Richter Scale and caused billions of dollars worth of damage. More than 50 people were killed and more than 8,000 injured.

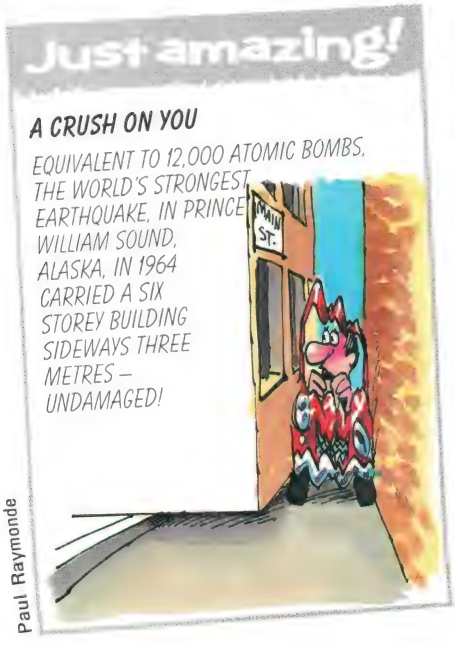
Tony Waltham

***'Quake-proof' buildings** with flexible internal supports are built in high-risk areas such as San Francisco.*



Gamma/Frank Spooner Pictures

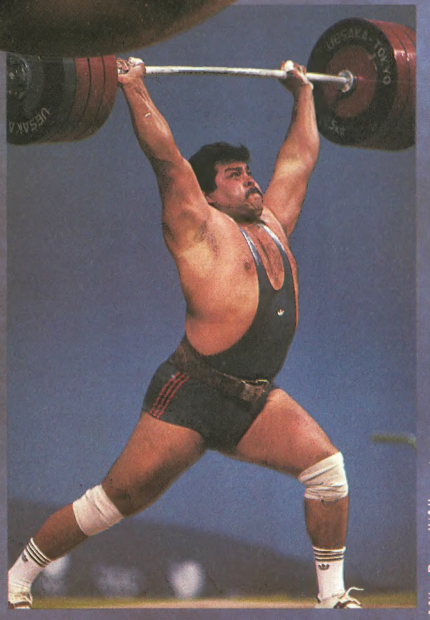
***Freeway horror:** the Californian quake of 1989 claimed over 270 lives. Many died when a motorway collapsed.*



Paul Raymonde

SUPERMEN

Bob Gardner/Muscle & Fitness



Mike Powell/Allsport

- MUSCLE TYPES
- RESPIRATION
- ANABOLIC STEROIDS

WHAT MAKES A GREAT athlete? The answer lies in a combination of different factors – genetics, attitude and training. Conventional wisdom has it that great athletes are born and not made.

Without doubt, the genetic make-up of the top sportsmen and women is a crucial factor in their success. For example, people born with a predominance of type 1 muscle, which is pale in colour, make ideal sprinters and jumpers. Those born with type II muscle will be good at long distance running. Only rarely do people born with one type of muscle excel in the disciplines which need the other muscle type. Sometimes fibre testing is used to select people for training for particular running events.

Some people are better equipped to deliver oxygen to their muscles – hence their performance improves.

Better breathing

The top athletes have an above average cardio-respiratory system, which means they are capable of a high rate of oxygen transport and carbon dioxide elimination.

Top athletes also appear to be genetically programmed to lay down less fat – adipose tissue – beneath the skin than the average person of the same age and sex. Having less fat means there is less weight to drag around and also makes temperature regulation more effective, so the athlete does not get too hot. Long distance swimmers, however, benefit from large amounts of fat under the skin as it helps keep them warm in cold water.

Body shape also helps determine how suitable someone is for certain sports. A tall athlete may be equally good at high-jumping or basketball,

***The rippling** muscles of the body builder are purely for posing. He would never be able to match the weight-lifter (above), as the narrow waists favoured by body builders would not be able to handle the strain of lifting up to 470 kg.*

whereas an oarsman with a powerful frame may also be a good rugby player. While sprinters tend to be broad-shouldered with muscular legs, the endurance athlete is lean, narrow-shouldered, and not too muscular in the legs. Middle-distance runners such as Sebastian Coe have slight figures compared to the powerful bodies of sprinters like Linford Christie.

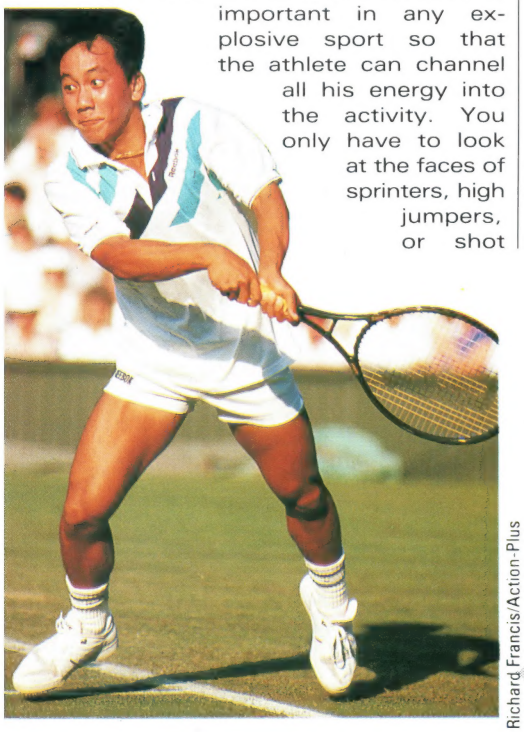
Though differences within a field may be small, they can determine who will become a world champion and who will be second-best.

Will to win

State of mind is an essential part of performance. In a sport like weightlifting, the athlete must psyche himself up for an explosion of power which is usually accompanied by a loud shout. Concentration is important in any explosive sport so that the athlete can channel all his energy into the activity. You only have to look at the faces of sprinters, high jumpers, or shot putters before they perform to see the intense concentration on their faces.

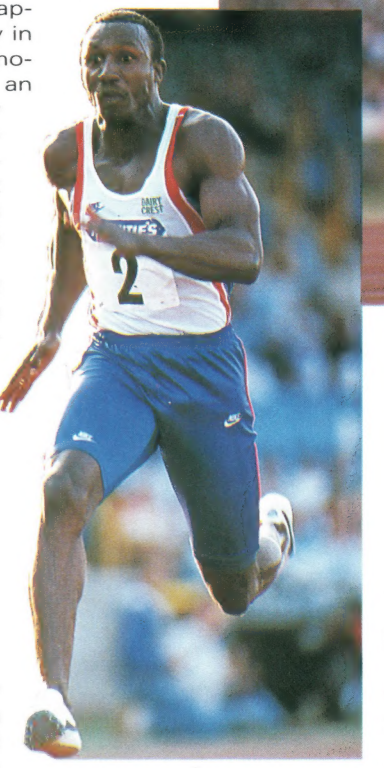
However, there are no golden rules which apply to all sports. For example, former Wimbledon tennis champions Bjorn Borg and John McEnroe had completely different temperaments. Borg showed no obvious tension and appeared to be totally in control of his emotions (he also had an abnormally low pulse rate). But McEnroe only seemed to play his best when he was wound up to the point of hysteria.

Self-belief and confidence are particularly important in sports where competitors are well matched – the 'will to win' can often be the deciding factor. Athletes try to boost their self-confidence by visualizing themselves performing at the peak of their ability. They hope to translate this mental rehearsal into success during the real competition. Sports psychologists can help athletes to think positively. Top English football club Tottenham Hotspur employed sports psychologist, John Syer, for a five-year spell in the 1980s which included three major cup wins.



Richard Francis/Action-Plus

Determination *is etched all over the face of teenage tennis star Michael Chang. While some players need to get 'hyped up' to play their best, others rely on keeping a cool head.*



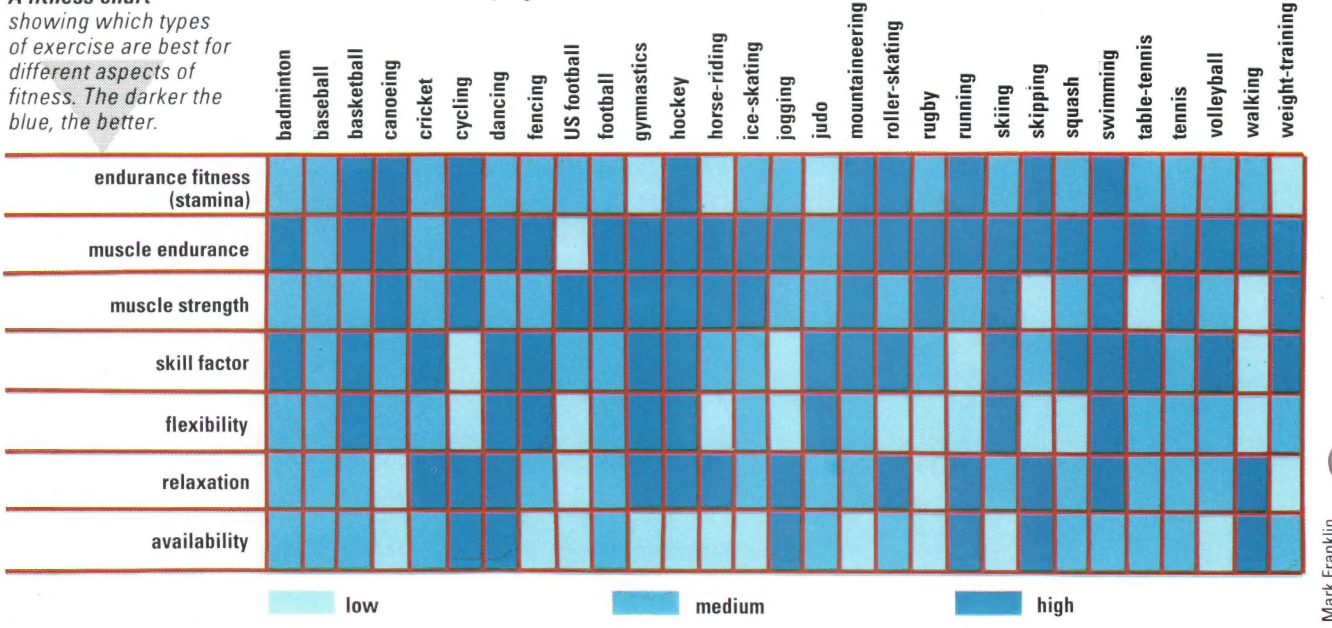
Gray Mortimore/Allsport

Middle distance *runners such as Steve Cram have a predominance of Type II muscle, helping endurance, while power athletes like Linford Christie (left) are much more likely to have Type I muscle in abundance.*

It is said that practice makes perfect. In some sports such as swimming, gymnastics and tennis, the top stars can reach the pinnacle in their teens, having trained intensively from an early age. But most athletes peak in their twenties, when they can combine athletic ability with the experience of competition.

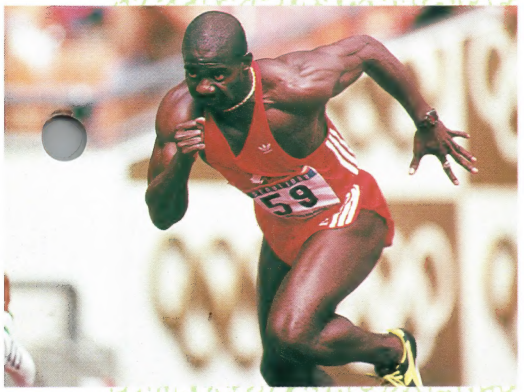
Training is vital to help athletes realise their genetically-endowed potential and reach the top. It helps them increase their strength, endurance and flexibility. In team sports,

A fitness chart *showing which types of exercise are best for different aspects of fitness. The darker the blue, the better.*



Mark Franklin

DRUGS IN SPORT



Tony Duffy/Allsport

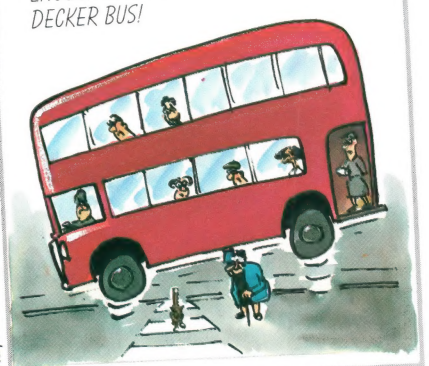
Many athletes and body-builders use anabolic steriods to build up their muscles. These drugs are based on the male sex hormorne testosterone and they enable athletes to build up more muscle bulk than drug-free athletes. But steroids are banned by most athletics organisations, partly because they are unfair on 'clean' athletes, and partly because of the harmful side effects. These include increased aggression, psychosis and brittle bones. Steroids increase the levels of testosterone, and some women have been known to grow excessive facial hair and stop menstruating. In severe cases, steroids can be fatal. They can be detected in urine samples, and it was this test which caught the Canadian sprinter Ben Johnson at the 1988 Olympics. He was subsequently stripped of his 100 metres gold medal and the 1987 world championship.

Another dangerous practice is 'blood-doping'. The athlete drains off up to a litre of blood, freezes it for a month, and then reinjects it close to an event. This increases the oxygen-carrying red blood cells. It is not illegal, but it is unfair.

Just amazing!

ALL FOR ONE

IF ALL THE MUSCLES IN A HUMAN BODY PULLED TOGETHER, THEY WOULD HAVE ENOUGH STRENGTH TO LIFT A DOUBLE DECKER BUS!

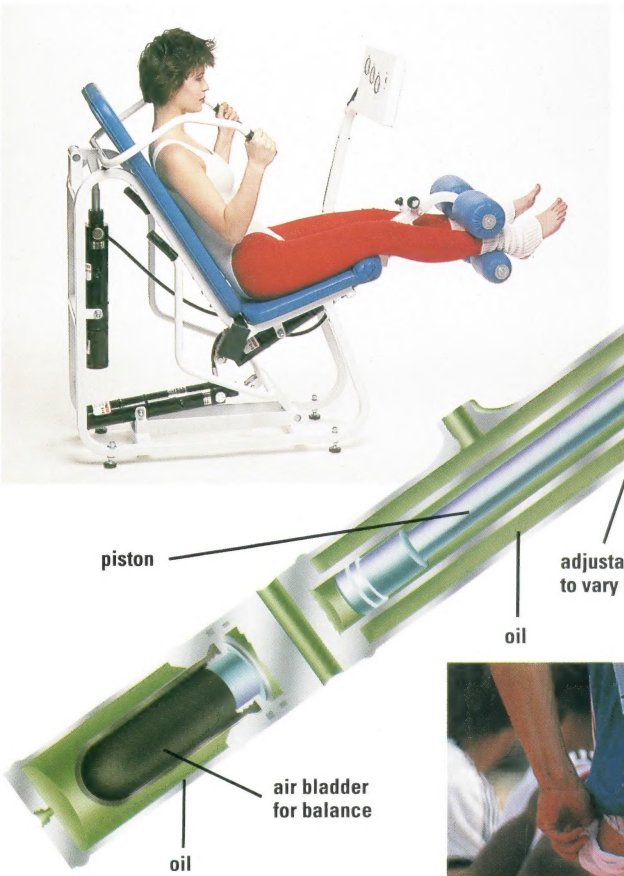


Paul Raymonde

training increases the players' awareness of each other.

In activities that demand a high oxygen supply to the muscles, training raises the capacity of the body to take in oxygen and transport it efficiently. When athletes are in full stride, the rate of blood flowing to the muscles is up to 30 times higher than normal thanks to a stronger heartbeat and faster heart rate than the average man. Regular exercise also increases the endurance capacity of the muscles.

In sports where skill is required, such as football or tennis, the level of ability can deteriorate as the athlete tires.



Hydra Fitness (Europe) Ltd

Hydra Fitness (Europe) Ltd/Mark Franklin

Hydraulic fitness *machines are safer than lifting free weights. Resistance is varied by slowing down the flow of oil inside the damper (below).*

Injuries *are a problem for all grades of athlete. Overtraining can be one cause, as well as the pressure to carry on when hurt, which increases the damage.*

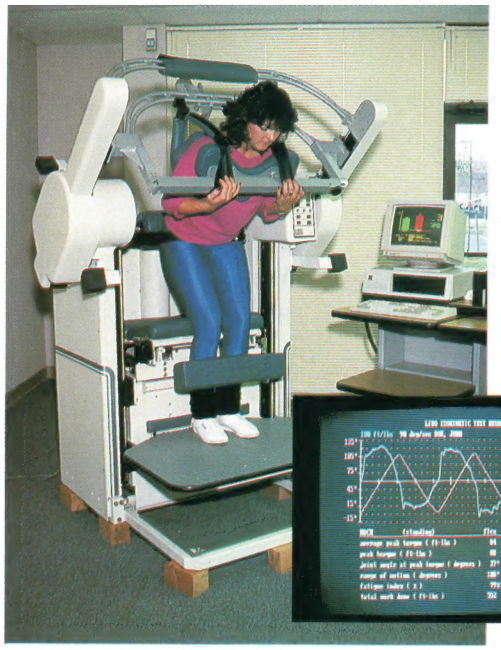
Action-Plus

Training science

Power training, such as weight-lifting, increases the size of muscle fibres and hence the size of the muscles. On the other hand, if muscles are not used they tend to waste away. Scientists are now developing techniques to make athletes fitter, faster, stronger and better than ever before. In recent years, scientists and doctors have played an important part in helping sportsmen and sportswomen reach new heights of performance.

Diet is particularly important for the endurance athlete, who may load up with carbohydrate in the days before a race. This builds up a reserve energy store of glycogen in the muscles and liver. Although fat can supply twice as much energy, it releases it more slowly. The top marathon runners are thought to obtain around 80 per cent of their energy from glycogen and only about 20 per cent from fat.

The recently opened Olympic Medical Centre in Northwick Park, London, is an example of what state-of-the-art sports science is now providing. For example, in the aerobic laboratory, athletes are tested for their ability to exercise while fuelling the muscles with oxygen — called aerobic respiration. The athlete is asked to work progressively harder by perhaps increas-



Rellford Medical Ltd

An isokinetic dynamometer *can be used to measure the strength and consistency of different groups of muscles. It displays the information on a computer screen (inset), and this will tell the athlete which muscles need working on most in training. Most of these machines can also be used to build up strength.*

Hank Morgan/Science Photo Library

The computerized *running shoe can tell you how much distance you have covered, how long it has taken, and your speed. The data is presented on a liquid crystal display.*

ing the angle of incline of a treadmill – a sort of conveyor belt whose speed is adjustable – and measuring the increasing amount of oxygen taken in at each breath.

Oxygen debt

When the oxygen uptake reaches a maximum, the body switches to anaerobic respiration – providing energy in the absence of oxygen. But this leads to a build up of lactic acid, a waste product that circulates in the blood and muscles and leads to fatigue and exhaustion. The pain in the legs after a long run is the result of lactic acid build-up, or 'oxygen debt' as it is known. Scientists take blood samples during testing to identify the point, known as the anaerobic threshold, where the lactic acid in the blood rises. This information is very helpful to athletes, because if they reach this threshold too quickly, they have to stop. The best way to train is to work just below the threshold.

An important test for people who play 'multiple sprint' sports such as football, involves working them flat out for 30 seconds and then measuring their performance. If the test is repeated 30 seconds later, it gives a measurement of the speed of recovery from fatigue, and their training can be adjusted to improve the recovery rate.

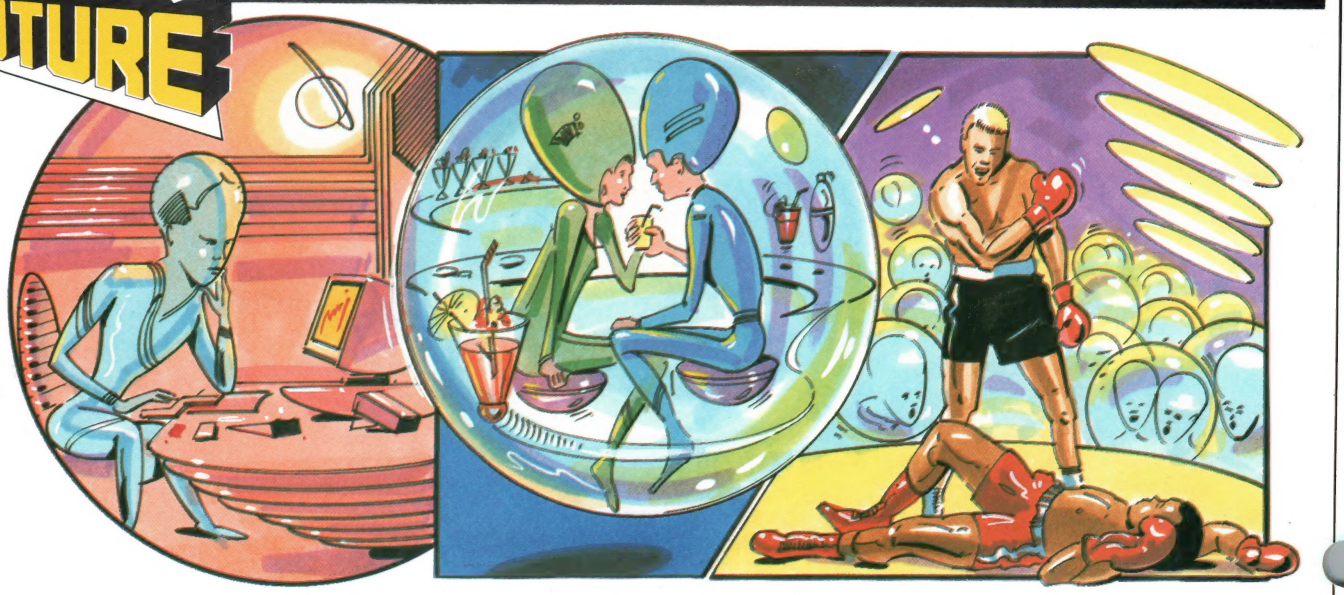
Overtraining

Training can sometimes be harmful. Gymnasts who start performing before they are ten can suffer crippling back pain by the age of 25, as a result of too much strain on their muscles and joints. Promising young tennis players have been racked with injuries after competing too hard from an early age.

Young people are particularly vulnerable to injury during the peak growth years, in their early teens. This is because as bones grow longer, they stretch the muscles and tendons anchored at the elbows, knees and ankles, which makes them more liable to injury. Young people must be instructed carefully to prevent 'burn out' later.

INTO THE FUTURE

MIND OVER MATTER



▲ *As technology takes more and more of the physical tasks away from Man he will evolve around his major organ – the brain.*

▲ *Eventually Man will learn to use his brain to its full extent, communicating by telepathy and moving objects by psychokinesis.*

▲ *There may still, however, be a need for some 'primitive' human models for entertainment work such as films and sports.*

Joe Lawrence